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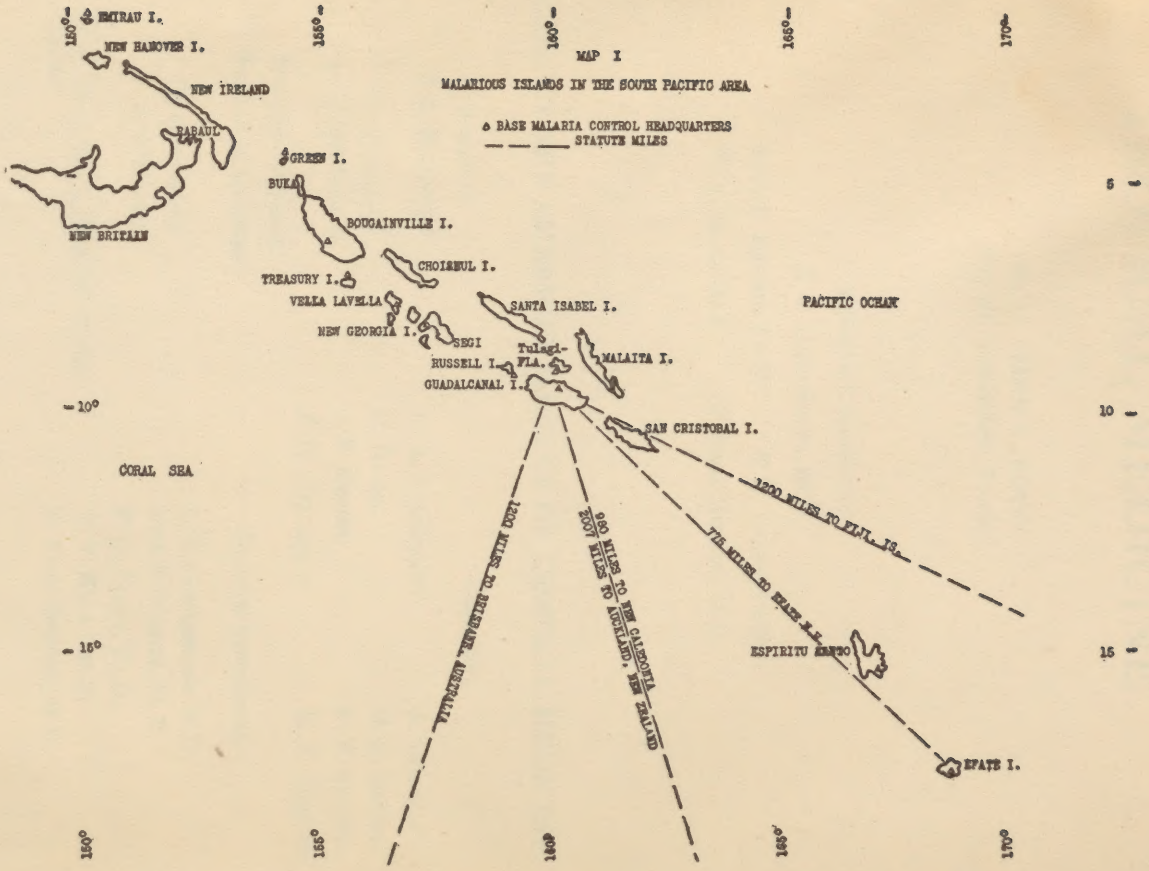
MAP I
MALARIOUS ISLANDS IN THE SOUTH PACIFIC AREA
BASE MALARIA CONTROL HEADQUARTERS
STATUTE MILES
EMIRAU I.
NEW HANOVER I.
NEW IRELAND
BARAUL
NEW BRITAIN
GREEN I.
BUKA
BOUGAINVILLE I.
CHOISEUL I.
TREASURY I.
VELLA LAVELLA
NEW GEORGIA I.
SEGI
RUSSELL I.
GUADALCANAL I.
Tulagi-
Fla.
SANTA ISABEL I.
MALAITA I.
SAN CRISTOBAL I.
PACIFIC OCEAN
CORAL SEA
1200 MILES TO FIJI IS.
776 MILES TO SANTO I.
ESPIRITU SANTO
EFATE I.
1200 MILES TO BRISBANE, AUSTRALIA
2000 MILES TO SOUTH END OF NEW CALEDONIA
2000 MILES TO AUCKLAND, NEW ZEALAND
150°
155°
160°
165°
170°
5
10
15
10°
15°

MALARIA AND OTHER INSECT-BORNE DISEASES IN THE SOUTH PACIFIC CAMPAIGN

1942–1945

A Series of Four Papers

TABLE OF CONTENTS

[1]All of the Contributors to this series of papers were commissioned officers in the medical Corps or Sanitary Corps, Army of the United States.

Foreword

Malaria was the most serious health hazard experienced by American troops in the South Pacific area during World War II. In spite of the fact that for many years we have known much about the etiology, treatment and prevention of malaria and the Army and Navy have long been aware of its military importance, this disease attacked approximately 100,000 men of the armed forces in the South Pacific, and for a short time jeopardized the success of the military campaign in that area. This situation, including difficulties in the transport of malaria control supplies and inadequate local provision for malaria control organization and malaria discipline among troops, was more serious in the Pacific during the early period of the war than in any other theatre or at any other time.

Fortunately, this undesirable situation was soon corrected and commanders, previously unimpressed with the military importance of malaria, took active steps to wage a campaign against the disease. Priorities were established which enabled the War Department to supply the specialized personnel required to deal with the problem, consisting of malariologists, malaria survey detachments, malaria control detachments, and other medical and sanitary personnel. Priorities were also set up which allowed the movement of malaria control supplies from the docks in San Francisco, and the Army and Navy cooperated in the development of an area-wide all services organization for the control of malaria which also proved effective in the control of other arthropod-borne diseases, including dengue, filariasis and scrub typhus.

This series of papers, I through IV, deals primarily with the malaria problem and includes brief discussions of the other insest-borne diseases. It summarizes the work and reports of many individuals and it attempts to present an area-wide perspective of the malaria control program which was spread over many thousands of miles on the eleven malarious and numerous non-malarious bases. The first paper deals with the background of the epidemics of insect-borne diseases and with the organization, the training program, and the control measures which were employed. Papers II, III, and IV describe respectively the epidemiological factors, the entomological problems, and the parasitological data of this important wartime malaria control program. These papers have been edited by Lt. Colonel Paul Harper, who was Chief Army Malariologist in the South Pacific Area and in general charge of the malariologists and malaria survey and control units in that area. The Medical Department of the Army is proud of the large group of its personnel who worked so effectively to bring malaria under control in such places as Guadalcanal, where this disease at one time severely threatened our Pacific operations. These men with their collaborators in the Navy did much to hasten the surrender of the Japanese.

James S. Simmons
Brigadier General, United States Army
Director, Preventive Medicine Division
Office of The Surgeon General

ACKNOWLEDGEMENT

We are grateful to Brigadier General Earl Maxwell, United States Army, Surgeon, United States Army Forces in South Pacific Area; to Captain Arthur H. Dearing, United States Navy, Force Medical Officer, South Pacific Area; to his successor, Captain Frederick R. Hook, United States Navy, and to Brigadier J. W. Twhigg, Director Medical Services, New Zealand Expeditionary Forces, Pacific, for their constant support of the South Pacific Malaria Control Organization and its work as described in the following pages.

We wish it were possible to give recognition to all those who aided in this work. Unfortunately this cannot be done. Special acknowledgement is made of the noteworthy contributions of Commander James J. Sapero, Medical Corps, United States Navy, Malaria and Epidemic Control Officer, South Pacific Area and of his successor, Commander F. A. Butler, United States Navy.

Appreciation is expressed to Colonel E. G. Sayers, Medical Corps, New Zealand Expeditionary Forces in Pacific for assistance developing from his special knowledge of tropical diseases in this area.

Acknowledgement is made to authorities in the Preventive Medicine Service of the Office of the Surgeon General, United States Army, including Brigadier General James S. Simmons, United States Army, Chief of Preventive Medicine Service, Office of the Surgeon General; Colonel Paul F. Russell, M.C., A.U.S., former Director Tropical Disease Control Division, Office of the Surgeon General; to his successor Lt. Colonel O. R. McCoy and to Colonel W. A. Hardenbergh, Director of Sanitary Engineering Division, Office of the Surgeon General. These officers contributed to the development of the basic organization of the malaria control program and provided continued support and assistance.

MALARIA AND OTHER INSECT-BORNE DISEASES IN THE SOUTH PACIFIC CAMPAIGN

1942–1945

I. General Aspects and Control Measures

P. A. HARPER,[a] E. T. LISANSKY[b] and B. E. SASSE[c]

A. INTRODUCTION

The epidemics of malaria and other tropical diseases which afflicted our troops in the South Pacific as they moved against the advancing Japanese called forth an organization and methods of prevention which proved that such diseases need not jeopardize the success of military operations in the tropics. The South Pacific Malaria and Insect Control Organization[1] was a joint Army-Navy-Allied group, and while these papers are concerned primarily with the organization of Army personnel, it is to be emphasized that the cooperative spirit within this joint service organization contributed immeasurably to its success. The broad outline of the problem has been described by Sapero and Butler, (1)[2] and the control program, by Butler (2). This and subsequent sections in this series of papers make free use of material from a confidential report, since unclassified.[3]

Both published and unpublished reports of several individuals are cited in this paper but this has not been possible in a larger number of instances. It is hoped that those who were associated with particular phases of the program will record their own observations.

B. EARLY EPIDEMICS

The causative factors for repeated and crippling epidemics of malaria among troops were present in the South Pacific Area. The indigenous natives, the European whites and the invading Japanese were heavily infected with malaria and constituted an ever present seed bed. There was an exceedingly efficient vector, *Anopheles* (*Myzomia*) *farauti* Laveran[4] and other members of this complex. Our troops were completely susceptible not only to malaria but to dengue, filariasis and tsutsugamushi fever, each of which caused localized but serious problems.

Malaria reached epidemic proportions among our forces on Efate and Guadalcanal. Lesser outbreaks occurred on Espiritu Santo, Tulagi-Florida, the Russell Islands, and Munda, New Georgia. No serious outbreaks of malaria occurred on Treasury, Bougainville, Green or Emiru Islands which were the last four bases

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[c] % International Health Division, The Rockefeller Foundation, 49 West 49th Street, New York 20.

[1] This organization was first known as "South Pacific Malaria Control," and later as "South Pacific Malaria and Epidemic Control."

[2] Numerals in parenthesis indicate literature cited.

[3] Harper, P. A., Butler, F. A., Lisansky, E. T.,and Speck,C. D., Malaria and Epidemic Control in the South Pacific Area, 1942–1944. Reproduced by Engineers, Headquarters, South Pacific Base Command, 2379 January 1945.

[4] Also erroneously referred to as *A. punctulatus* Doenitz and *A. punctulatus* var. *moluccensis* (Sw. and Sw.).

to be occupied because the malaria control program on these bases was adequately organized and supported from the time of the initial landings.

The epidemics at Efate and Guadalcanal indicate the seriousness of the early situation on the first malarious bases to be occupied in this area (Table I).

Efate was occupied in March 1942 by a few hundred allied troops who landed to build an airfield and to forestall the southward advance of the Japanese. Their bivouac site near the airfield was surrounded by anopheline breeding swamps and streams. Native laborers employed on the project were encamped nearby. A Marine defense battalion enroute to a non-malarious base was diverted to Efate and landed in April 1942. Their supply of anti-malaria drugs was inadequate, and their bed nets were deep in the ship's hold and not available for two weeks. Night work was a military necessity. The malaria rate of 2600 per 1000 per

TABLE I

Early malaria rates per thousand per annum for all forces, Efate and Guadalcanal*

YEAR	MONTH	EFATE	GUADALCANAL
1942	April	2678	
	May	982	
	June	915	
	July	518	
	August		14
	September		177
	October		1664
	November		1781
	December		972
1943	January		1169
	February		878
	March		1052

* See Graphs I & III, Paper II.

annum on Efate in April 1942 ensued from the close association of unseeded troops, infected natives and anophelines.

The first troops on Guadalcanal in August 1942 found few mosquitoes and in the early weeks had little malaria. Native laborers and the Japanese were the reservoir of infection. *Anopheles farauti* found ideal breeding places in the myriad ruts and holes made by the occupying forces and rapidly produced enormous populations. Malaria control measures received scant attention in September and October of 1942 because of the desperate military situation. Combat conditions and a small perimeter contributed to the factors required for an epidemic; namely, susceptible troops, anopheline mosquitoes and a seed bed of malaria in natives and Japanese. A few cases of malaria appeared in September, the disease became epidemic in October, with a peak case rate of 1800 per 1000 per annum in November. The epidemic lasted for nearly a year and the case rate averaged more than 1000 per 1000 per annum for eight months. A large part of

the malaria seen throughout the duration of the South Pacific Campaign represented infections and relapses from infections contracted during these early days on Guadalcanal.

Malaria caused more than five times as many casualties in the South Pacific as did combat. It is estimated that a total of 100,000 individuals, Army, Navy, Marine and Allied, contracted malaria in this area. Each of these individuals had an average of nearly two attacks, thus doubling the loss of man days.

Heavily infected troop units which were sent from Guadalcanal to rear bases and ordered to stop suppressive atabrine averaged 1½ to 2 attacks of malaria per man before resuming suppressive therapy.[5] Entire divisions were rendered both less effective in combat and during the period of rehabilitation because of the number of men ill with malaria.

The urgent military situation and the shortage of supplies was partially responsible for these early malaria epidemics. It was necessary to occupy Efate, Santo and Guadalcanal months before the arrival of trained malaria control personnel and equipment, over a year before the new repellents and freon aerosol insecticide dispensers were available, at a time when the supply of quinine was limited and when atabrine was still an unfamiliar drug. Although it was known that malaria alone could incapacitate an army and although information existed on how to deal with the problem, this knowledge, for reasons here given, was not applied in the South Pacific Area until devastating epidemics of malaria made prompt action imperative. The concept of "malaria discipline" had not been developed and the prevailing attitude was well expressed by one high ranking officer on Guadalcanal who said, "We are out here to fight Japs and to hell with mosquitoes."

The Japanese who also suffered severely from malaria, were less successful in their control efforts. There is evidence that uncontrolled malaria, beriberi and dysentery were among the decisive factors which cost the Japanese the Guadalcanal and Munda campaigns. The few prisoners taken throughout the campaign were in general emaciated, suffering from dysentery or helminthic diseases and almost invariably malarious.

Examination of Japanese base areas in the Solomons revealed little evidence of semipermanent malaria control. A few ingenious and efficient knapsack sprayers and small quantities of larvacidal oils were found. The Japanese used bednets, a repellent cream whose active ingredient was oil of citronella, and a form of punk for producing smoke with mosquito repellent properties. Although the Japanese had a large quantity of both quinine and atabrine, it seemed likely from allied intelligence reports that the supply was often exhausted in isolated garrisons.

The weakening of Japanese resistance by disease was not a completely favorable circumstance. Highly malarious Japanese undoubtedly infected a large percentage of the Anopheles mosquitoes in their vicinity. During ground combat and after occupation of Japanese positions by Allied troops, infected mosqui-

[5] See Paper II, Graphs VIII and IX of rates in Americal Division and in 147th Infantry during discontinuation of atabrine suppressive medication.

toes transmitted much malaria from Japanese to American troops. Japanese were in some instances the principal source of infection for sudden outbreaks of malaria in front-line American troops. A sharp outbreak of malaria on Bougainville affecting many hundreds of Allied troops several months after occupation was directly traceable to seizure of a front-line area on Torokina River recently held by Japanese.

Table II was compiled from captured Japanese medical reports[6], for Japanese forces in the Solomons, New Britain, and New Guinea during the period December 1942 through February 1943. A translated Japanese Medical Service Report[7] for this period is quoted: "At Rabaul . . . during the month (of February 1943) 32.4% (605 men) of the Hq Sig Unit became malaria patients and of the 41st Inf Regt, 22.09% (716 men)". During the month of April 1943 the total malaria rate for Rabaul and vicinity was 2053 per 1000 per annum, according to other captured documents.

Dengue fever reached epidemic proportions on Fiji, New Caledonia, Efate and Tulagi-Florida although its importance was obscured by the deluge of malaria. It caused illness in over 25 per cent of the military population on Santos in the

TABLE II

*Malaria in Japanese forces**

MONTH AND YEAR	STRENGTH	MALARIA RATE PER 1,000 PER ANNUM (NEW PATIENTS)	MALARIA DEATHS
December 1942	51,382	450	1
January 1943	61,501	1,098	8
February 1943	79,901	1,637	13

* Captured medical data, Solomons and Bismarck Archipelago, compiled by Commander F. A. Butler, M.C., U. S. N.

first half of 1943 and resulted in over 80,000 sick days on this base alone before it was brought under control (3).

An extremely severe epidemic of filariasis which occurred in the Samoan Defense Area led to the medical evacuation of many thousands of troops. This offered an unusual opportunity to study the beginning of this disease in freshly exposed adults. It was demonstrated that the disease syndrome called "Mumu" by the natives was an early manifestation of infection with *Wuchereria bancrofti*. This syndrome was characterized by localized swellings, retrograde lymphangitis, lymphadenitis and by genital manifestations (4, 5, 6, 7, 8). Volumes 42, 43 and 44 of the United States Navy Medical Bulletin contain nine papers on this epidemic of filariasis. The report by Byrd et al. (9) describes the entomological and parasitological investigations which were fundamental to controlling the disease. Subsequent surveys on nearly every South Pacific Base showed a high incidence of filarial infection in natives, Paper IV.

[6] Harper et al. cited in footnote on page 1.

[7] Allied Translator Intelligence Service, South West Pacific Area Current Translations No. 121 dated 28 May 1944.

Over 75 cases of tsutsugamushi disease occurred on Bougainville, 49 of which are reported in (10). Three isolated cases occurred on Santos[8] and about 10 unconfirmed cases were reported from Munda, New Georgia.

The control of all these arthropod-borne diseases became the responsibility of the South Pacific Malaria and Insect Control Organization.

C. PHYSICAL GEOGRAPHY, HISTORY, PERIOD OF OCCUPATION

The genesis of the epidemics of insect-borne diseases that occurred in the South Pacific was found in the combined factors of physical geography, infected natives, a potent vector and the impact of military activities

The South Pacific Area eventually expanded to embrace 11 malarious bases in the New Hebrides, the Solomon Islands, Green Island and Emiru Island (St. Matthias group), the last 2 being part of the Bismarck Archipelago. The occupied malarious islands (map of malarious islands in the South Pacific Area, frontis-piece) form a long chain extending from southeast to northwest, with Emiru 1°8′ S.L. and 150° E.L. at the northwest end and Efate 17°30′ S.L. and 168°30′ E.L. at the southeast end. The total distance from Efate to Emiru is about 1550 nautical miles. The Coral Sea and Australia are southwest of this island chain and the Pacific Ocean is north and northeast. In addition, New Caledonia, New Zealand, Fiji, Samoa and other non-malarious islands were used for staging and for rehabilitation of troops from malarious and combat areas.

The major islands of both the New Hebrides and Solomons are of volcanic origin. Coastal areas on many islands are composed of upthrust coral formations which form the subsoil. The topsoil of all coastal plains is alluvial. Green and Emiru Islands are of coral origin. The total area of the New Hebrides is 5,700 square miles; that of the Solomons is 18,000 square miles. The largest island in the New Hebrides, Espiritu Santo, is 76 miles long and 40 miles wide. Efate is 26 miles by 14. The largest island in the Solomons group is Bougainville, with a length of 120 miles and an average width of 40 miles. Guadalcanal, the second largest Solomon Island, is 90 miles in length with an average width of approximately 30 miles. All the islands are covered with dense jungle rain forest or high tropical grass. Coconut plantations are found along the flat coastal plains of many of the islands.

All of the major islands are mountainous. On Bougainville in the Solomons, Mount Balbi reaches to 10,171 feet. Mt. Popomanasni on Guadalcanal is 8,005 feet high and Mt. Tabwemasana on Espiritu Santo reaches 5,940 feet.

Numerous streams are present on the larger islands and are fed by abundant rainfall. They are, in general, short and rapid, although often tending to become sluggish, spreading, and swampy on the level coastal plains and valleys. Mangrove swamps are occasionally found. A high pounding surf on several islands has caused sandbar dams which block streams and produce numerous fresh water lagoons and marginal fresh water swamps.

The temperature throughout the Solomons at sea level varies from a maximum

[8] Essential Technical Medical Data, South Pacific Base Command, Sept. 1944.

TABLE III

Rainfall (inches)—Solomon Islands

STATION AND YEAR	SOURCE	MONTH												TOTAL
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Tulagi														
1926	A	14	13	4	12	5	5	2	9	8	3	13	9	97
1932	A	17	10	5	11	8	7	9	13	9	7	19	12	127
1936	A	21	14	11	9	10	12	12	4	11	12	5	5	126
Florida (Halavo)														
1943	B									6	11	5	18	
1944	B	16	15	20	12	8	8	10	13	14				
Guadalcanal														
Lunga Point														
29 yr. pre-war avg		13	10	12	7	4	3	3	3	4	4	6	7	76
Henderson Field														
1943	B			2	4	9	3			1	3	2	7	
1944	B	13	17	12	10	5	5	6	4	5				
Carney Field														
1943	B							3	1	2	3	3	11	
1944		14	15	11	10	7	5	6	4	4				
Doma Cove														
1944	B	15	20	9	8	3		4	3	6				
Russells (Banika)														
1943	B					16	4	3	8	3	12	5	3	
1944	B	18	19	14	20	12		11	7	7				
Vella Lavella														
Nyanga														
1931–1937 avg	C	18	14	15	11	10	8	9	8	7	9	9	8	126
1931–1937 max	C	28	21	22	22	13	12	14	13	14	18	13	15	
1931–1937 min	C	7	10	7	4	6	5	7	5	5	3	4	5	
Bilca														
1943	B										5	4	15	
1944	B	19	25	6	10	7								
New Georgia														
Segi														
1943	B												9	
1944	B	16	8	15	11	9								
Munda														
1943	B									10	11	9	14	
1944	B	17	16	12	13	12								
Bougainville (Kieta)														
1916–1937 avg	D	11	11	11	11	10	9	11	10	8	10	10	9	121
1916–1937 max	D	20	36	34	22	16	20	22	20	16	27	16	19	
1916–1937 min	D	5	3	4	4	4	4	5	2	2	4	3	1	

A—Pacific Islands Year Book. B—Data collected by U. S. Weather stations and malaria control units. C—Hq USAFISPA Intel. Folder, Ref. No. SPOF-8. D—Hq USAFISPA Intel. Folder, Ref. No. SPOD-9.

of about 95° to a minimum night temperature of approximately 70°. The humidity is high. One can always sleep comfortably cool at night even when

the days are extremely hot and humid. The prevailing wind is from the southeast from April to the beginning of November. From November until the end of March, calms may be expected, with an occasional spell of heavy northwest weather, sometimes continuing for 1 to 3 weeks. Hurricanes do not occur and winds are usually gentle except when accompanied by rain.

Table III presents the available data on rainfall in the Solomons. The rainy season usually begins in November or December and extends through March or April.

The climate of the New Hebrides is similar to that of the Solomons except that temperatures average slightly lower and the annual rainfall is somewhat less. Minimum temperatures are recorded at 53° at Segond Channel on Espiritu Santo and about 58° at Efate, with maximum of 98° and 93° respectively. The prevailing wind, as determined at Segond Channel, is southeast during all months of the

TABLE IV

Rainfall (inches)—New Hebrides

STATION AND YEAR	SOURCE	MONTH												TOTAL
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Tanga I.														
1926–1943 average	A	11	10	12	9	8	6	6	6	4	7	8	10	98
Espiritu Santo														
Segond Channel														
1926–1943 average	B	15	16	10	10	13	6	5	5	8	6	10	12	116
1943	C	7	5	22	9	11	7	3	2	6	20	12	8	112
1944	C	13	14	28	19	7	3	8	5	6				
Efate (Vila)														
1943	C			13	11	1	3	3	1	5	10	10	7	
1944	C	13	13	15	14	5	3	5	3	6				

A—Records of Presbyterian Mission School, Tangoa, N. H. B—Monthly Weather Review, Segond, Espiritu Santo, N. H. C—Data collected by U. S. weather stations and malaria control units.

year. The New Hebrides also are classified as an unhealthy area, primarily because of malaria.

Table IV presents data on rainfall. Tangoa Island and Espiritu Santo are both in the northern section of the New Hebrides, while Efate is in the southern. Variability of monthly rainfall from season to season and year to year is evident here as in the Solomons, but the rainy season extends from October or November through April or May. Rainfall of 10.5 inches occurred in one 24 hour period, 27 March 1944, on Espiritu Santo.

Guadalcanal and other islands of the southern Solomons were discovered and named by Alvaro de Mendana de Negra in 1567. Bougainville was discovered by the French navigator of that name in 1768.

The Solomon Islands are divided into 2 governmental areas. Bougainville and Buka are part of the Australian Mandate received from the League of Na-

tions in 1920, and are normally administered from Kieta, Bougainville. All the other islands are a British protectorate, proclaimed in 1893, with a British Resident Commissioner at Guadalcanal who is responsible to the British High Commissioner of the Pacific at Fiji.

The principal product of the islands is copra, although small amounts of timber, ivory nuts, trochus shell and green snail shell are also exported. About 5,000 natives are normally employed on the plantations. The value of all exports before the war ranged from 100,000 to 400,000 pounds sterling a year.

The New Hebrides Group was discovered in 1606 by the Spaniard, Pedro Fernandez de Quiros, formerly navigating officer to de Mendana. He was under the impression that he had found the long-sought "southern continent" and he named it Tierra Australis del Espiritu Santo, whence came the name of the island of Espiritu Santo. Cook charted the greater part of the group in 1774.

The New Hebrides are governed by a joint British-French Condominium, established in 1906. The British Resident Commissioner is responsible to the High Commissioner at Fiji, and the French Resident Commissioner to the French High Commissioner at Noumea, New Caledonia.

Copra is the chief export, although cocoa and coffee production are also significant. Labor is largely provided by Indo-Chinese (Tonkinese) whom the French brought in. Exports from the islands have been valued at more than 100,000 pounds sterling a year since 1930.

The population of the Solomons, including the Bougainville area, in 1939, was given as 500 whites, 140,000 Melanesians and 200 Chinese. About 20,000 of the Melanesians lived on Guadalcanal, and 45,000 on Bougainville. The indigenous natives of the main Solomons group are Melanesians, although an admixture of Polynesian is evident on certain islands. The peoples of the outlying islands of Ontong Java, Sikiana, Rennell, and Bellona are Polynesian. The natives live rather primitively in small villages or as single families.

Malaria is prevalent among the Europeans and cases of blackwater fever have been reported among them. The Melanesian natives are heavily infected with tuberculosis, filariasis, yaws, and hookworm. Venereal disease is uncommon and syphilis is unknown. Malaria is hyperendemic among the natives. Every person in many localities has had the disease repeatedly before reaching adulthood. The results of pre-war surveys by Sayers and Innes and of numerous surveys by malaria survey groups in 1942–1944 are given in paper IV. The population is said to be declining among those natives who have frequent contacts with the whites and to be increasing among the remaining natives.

The population of the New Hebrides in 1939 was given as 218 British, 687 French, 2,282 Asiatics (Tonkinese, Chinese and Japanese) and about 40,000 Melanesians. Approximately 4,000 natives are thought to be on Espiritu Santo and 1700 on Efate. The indigenous natives of the New Hebrides are Melanesians.

The health status of the New Hebridean natives is generally poorer than that of the Solomon Islanders. The population is steadily declining on almost all

islands. Tuberculosis is common and has a rapid fulminating course among the natives. Yaws, hookworm, the dysenteries, and filariasis also have a considerable incidence. Malaria is hyperendemic among most of the New Hebrides natives.

The initial occupation of the New Hebrides and Solomon Islands by the United States and New Zealand forces can be divided into two phases: the peaceful occupation of the New Hebrides during the first half of 1942, and the occupation by amphibious assault of the Solomons and Bismarck Archipelago bases (August 7, 1942 through March 1944).

The chronological table for occupation of malarious islands is as follows:

a. Efate—advance group landed March 18, 1942. Main landings in April and May, 1942.

b. Espiritu Santo—unopposed landings on May 4 and 28, 1942.

c. Guadalcanal—Amphibious assault on August 7, 1942. Island secured February 9, 1943.

d. Tulagi and adjacent islands—amphibious asault on August 7, 1942. Island secured August 9, 1942.

e. Russell Islands occupied without opposition on February 21, 1943.

f. New Georgia—Amphibious assault (Rendova) on June 30, 1943. Area secured on August 26, 1943.

g. Vella Lavella—Amphibious assault on August 15. Island secured on October 9, 1943.

h. Treasury Islands—Amphibious assault on October 7, 1943. Organized resistance ceased in three days.

i. Empress Augusta Bay, Bougainville—Amphibious assault on November 1, 1943. Perimeter defense until V-J day.

j. Green Island—Amphibious assault on February 15, 1944. Island secured on February 20, 1944.

k. Emiru—Occupied on March 20, 1944.

Enormous changes were brought about by the Japanese and American occupations of these islands. Small perimeters were crowded with thousands of men engaged in diverse activities. Thirty airfields were constructed by Americans throughout the area and approximately eight by the Japanese. Hundreds of miles of all-weather heavy-traffic roads were constructed by the American forces, and thousands of large storehouses, metal huts, hangars, and wood buildings were erected. In many places bitter battles were fought over jungle areas, grass lands and swamps, leaving in their wake a wasteland of shell holes, bomb craters, fallen trees, broken equipment, and other debris of battle. Following the battles, previously uninhabited bays and coves became important harbors, with nearby hospitals, supply bases, staging areas and recreational grounds.

D. AREA ORGANIZATION AND PROCEDURE

The South Pacific Force under Navy Command was a joint U. S. Army, Navy, Marine, and New Zealand group. Commander, South Pacific (ComSoPac) was

the senior Navy Command. The senior Army Command within the area was United States Army Forces in the South Pacific Area (USAFISPA). Island Commanders were responsible to Commander, South Pacific, and Commanding General, USAFISPA. On each base there was an Army Service Command and a Naval Headquarters, each responsible to the Island Commander. Commanding Generals of divisions, if on established bases, were responsible to Island Commanders on matters pertinent to that base.

1. Legal Basis and Development of Area Organization

At the height of the initial malaria epidemic which occurred on Efate, it was requested that an experienced Navy malariologist be sent to Efate to initiate malaria control measures. This officer arrived without a staff or equipment in July 1942. Additional personnel was secured, trained and assigned; directives were issued, and the South Pacific Malaria and Insect Control Organization[9] herein described was gradually formed.

The slow development of this organization is worthy of comment. It required time to procure and train personnel in the problems of entomology, engineering and malariology peculiar to this area. Only after field trial was it possible to develop a staff for area headquarters and to make those transfers which were essential to build a strong organization. The directives which formed the legal basis of this organization and established malaria control policy were written and rewritten as new problems were encountered for a period of more than 2 years. The first directive[10] was issued in September 1942 and called attention to the existence of a "malaria control unit," available for use on the 3 bases then occupied, Efate, Espiritu Santo, and Guadalcanal. This directive was issued to publicize the malaria control organization, and in particular to make it available to Espiritu Santo and Guadalcanal, which had been occupied in the preceding weeks. At this time, September 1942, the small number of malaria control personnel in the area was almost entirely Navy, but the mixed service aspect of the organization was foreshadowed by the assumption that this organization would provide malaria control for all services and forces.

Two officers and 8 enlisted men were sent to Espiritu Santo in September 1942 to set up the Base Malaria Control Unit there. Despite the fact that the Guadalcanal malaria rates were rising ominously, no malaria control personnel was allowed to begin operations there until mid-November, when the malaria epidemic was in full swing and anopheline breeding had reached a high level. Such an attitude towards malaria control measures was partly due to the desperate military situation in September and October 1942. However, it was typical of the prevailing opinion that malaria and malaria control were of minor importance during combat operations.

The difficulties in establishing malaria control on Guadalcanal despite the obvious need made it increasingly evident that a stronger area directive was

[9] See footnote on page 1.

[10] ComSoPac Serial 301e, dated 2 Sept. 1942.

necessary. Such a directive[11] was issued in November 1942 and is quoted in part:

"Malaria control units, with headquarters at Base Roses (Efate), have been and are being established at various bases in the South Pacific Area. Each unit consists of a medical officer in charge, an entomologist, and laboratory and field technicians who are specialists in problems of malaria control. These units will advise and render service in connection with malaria control to U. S. Army, Navy and Marine Corps Units and Allied Forces occupying malaria infested islands.

"It is the responsibility of the Malaria Control Units to: (1) make epidemiological studies pertaining to malaria, (2) operate laboratories for diagnosis, (3) train personnel from other organizations in laboratory procedures pertaining to malaria control, (4) advise in regard to mosquito control measures, (5) advise in regard to disinsectization of aircraft, (6) make such recommendations to the proper authorities in regard to malaria control as the circumstances require, (7) procure, store and distribute antimalarial drugs for chemoprophylaxis as may be required by the forces at each base.

"A laboratory section of a Malaria Control Unit will be established at certain non-malarious bases. The officers in charge of these units will carry on studies of malaria infected personnel evacuated from malarious bases and will make recommendations with respect to treatment of and malaria control measures pertaining to evacuated personnel. They will also undertake training of laboratory and medical field technicians attached to organizations preparing to enter malarious bases in the special procedures applicable to malaria control.

"Personnel of Malaria Control Units will be attached to the major medical department activity of the base to which the unit is assigned for administrative purposes, berthing and subsistence. The major medical department activity will also provide laboratory facilities for these units.

"The Commanders of all bases in which Malaria Control Units are established are enjoined to cooperate to the fullest extent with the officer in charge of Malaria Control Units in order that these units may accomplish their extremely important mission. It is directed that officers in charge of malaria control units be consulted in connection with the selection of sites for camps and airfields and that their recommendations in such matters be given due consideration."

This and numerous other directives governing malaria and epidemic control operations were later consolidated into a new directive.[12] There were several significant changes in this new directive. Par. 3b stated that a secondary function of the Malaria Control Organization was to organize and carry on control of epidemic diseases other than malaria. Important excerpts from this directive are quoted:

"Organization and Responsibilities

"a. Pertaining to the area program of control. A Malaria and Epidemic Control Officer on the Staff of Commander South Pacific has cognizance of all matters pertaining to the

[11] ComSoPac Serial 0094b, November 13, 1942, and a similar directive by USAFISPA published November 29, 1942.

[12] ComSoPac Serial 002263, dated 24 October 1943, General Information Circular, A11-1/MC/(75); and Memorandum 169, Hq USAFISPA dated 19 November 1943.

control of malaria in all forces in the area. He makes recommendations to the Commander South Pacific for the overall area program of control and recommendations for the establishment of Malaria Control Units at bases, and the administration and coordination of malaria and epidemic control. (ComSoPac Serial 0094b, 13 Nov. 1942).

"An Area Entomologist and an Area Engineer serve to coordinate efforts in their special fields. A Training and Education Officer is responsible for an educational program of practical measures of malaria prevention for all shore-based forces in the Area. He prepares such educational material as malaria training manuals for line and medical officers, and for enlisted men. Posters, films and other useful training aids are distributed.

"b. Pertaining to the control program at malarious bases. The senior Malaria and Epidemic Control Officer of base units is directly responsible to the Island Command for an effective program of control, applicable to all forces at the base. He formulates the control program for the base and makes recommendations to the Island Commander who in turn will require subordinate units to carry out prescribed control measures within their respective commands.

"Reports of the senior base Malaria and Epidemic Control Officer are submitted directly to the Island Commander. Copies of such of these as are pertinent are forwarded directly to the senior subordinate commands of the various services at each base, to the Force Medical Officer, Commander South Pacific, the Surgeon, USAFISPA and Headquarters, Malaria and Epidemic Control.

"Base Malaria Control Units are permanently established and serve all forces without service distinction. The units are jointly constituted, being composed of specially trained Army and Navy personnel—malariologists, entomologists, engineers, parasitologists, and laboratory and field enlisted technicians.

"Control operations are carried on under the technical direction of Base Malaria Control Units by the following:

(1) *Naval construction battalion sanitary sections* consisting of 110 men, together with certain heavy equipment. (ComSoPac 01227, 31 July 1943).

(2) *Army sanitary companies* performing light engineering duties especially oiling.

(3) *Native labor*, available at certain of the bases, to carry on clearing operations.

(4) Mosquito control squads formed within all tactical and service groups.

(5) Full construction battalions and other units specially designated by Commander South Pacific for malaria control."

The malaria control unit described in this directive, or malaria control group as it was subsequently called, consisted of a malariologist; one or more army malaria survey detachments, comprising an entomologist, a parasitologist and 11 enlisted men; one or more army malaria control detachments comprising a sanitary engineer and 11 enlisted men; or equivalent navy personnel. The command channels of this group are discussed below and are shown in Chart II.

The Area Malaria and Epidemic Control Organization grew and developed as the area expanded from 1 to 11 malarious bases, as the legal basis was broadened and as the personnel increased from 1 officer and 3 enlisted men in July 1942 to over 750 technically trained personnel and nearly 4000 laborers in June 1944. This growth made clear the need for an area staff which was developed in the following order of appointment: An Area Malaria and Epidemic Control Officer; an Area Entomologist; an Army Liaison Officer; an Area Training and Education Officer; an Area Administrative Assistant; an assistant Malaria and Epidemic Control Officer; an Area Engineer and two Filaria Survey Officers.

The duties and responsibilities of the area organization were gradually developed:

a. It served all forces on the basis of its area wide authority and joint U. S. Army-Navy and Allied organization.

b. It formulated area directives which defined and gave authority to insect and rodent control policy, organization and function.

c. It made recommendations for the procurement, assignment and transfer of all control personnel.

d. It provided technical and supervisory assistance to the various base and division malaria and insect control groups.

e. It was responsible for the control work of the base groups and established a uniform system of reports and inspections to allow assumption of this responsibility.

f. It recommended allowances and provided for procurement and distribution of malaria control equipment and supplies.

g. It provided a uniform and area-wide educational and publicity program of malaria and insect control for all personnel, and special information for line officers, medical officers and for personnel assigned to malaria control work.

h. It made personnel and equipment available for special problems of malaria control such as airplane application of DDT solutions and spraying of bed nets with DDT and for problems concerned with filariasis, mite-borne typhus, dengue and rodent control.

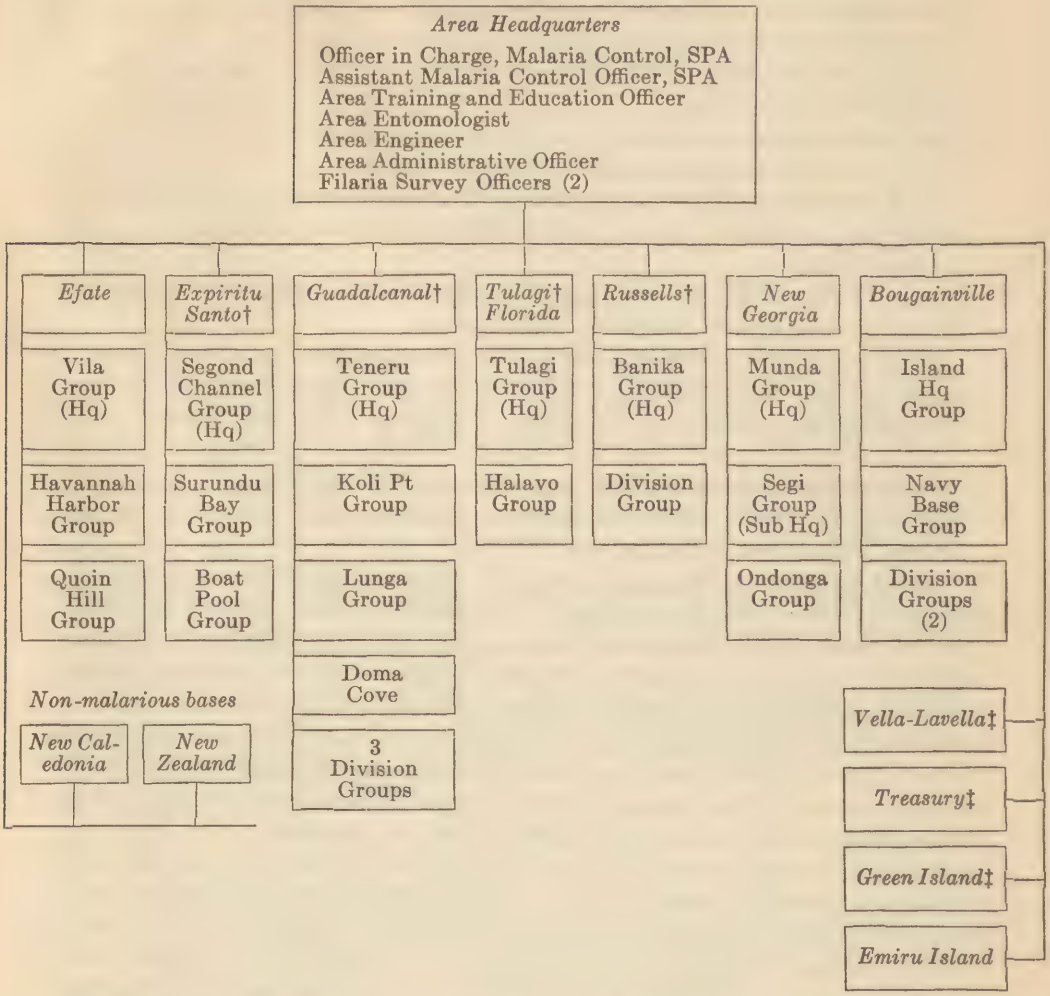
Chart I shows the functional personnel of the Area Organization and the distribution of base and division groups. The members of the area staff had letter orders allowing travel throughout the area. An officer from headquarters made a complete circuit of the bases every 4 to 8 weeks to check on supplies and personnel needs and to discuss current problems. One indication of the enthusiasm and performance of these base units was their pride in their work and their desire that every new project should be visited on these inspection trips. The visiting officer clambered along drainage ditches, slogged through swamps and visited native villages on one base after another until he returned to headquarters, thoroughly exercised and well informed. The area entomologist and engineer often stayed several weeks at a base where current problems required their presence and gave technical and supervisory assistance through personal contact with the corresponding officers in each base unit. Distribution of technical information was also accomplished through the News Letter and special publications such as synoptic keys to mosquitoes. Uniform methods of reporting information were adopted for all base reports as well as for area reports.

2. Extension of Work to Control of Filariasis, Dengue, Tsutsugamushi Disease and Rodent Control

It was discovered that the chief vector of malaria in the South Pacific Area, *Anopheles farauti Laveran* was also the most important vector of filariasis in the Solomon and New Hebrides Islands.[13] *Anopheles Kolicnsis* was also found to be

[13] Byrd, E. E. and St. Amant, Studies of Filariasis. Newsletters 14 and 16, August and October, 1944. Headquarters Malaria and Epidemic Control. South Pacific Area.

CHART I. BASE MALARIA AND INSECT CONTROL GROUPS*
Division malaria and insect control groups, South Pacific area (1 June 1944)



* The term Malaria and Insect Control Group is used to designate a working organization comprising a malariologist, one or more army malaria survey detachments and one or more army malaria control detachments or equivalent navy personnel.
† Rodent Control Units were also stationed on these bases.
‡ Malaria Control Personnel of 3rd New Zealand Division as well as Island Headquarters group.

a vector of Filariasis on Guadalcanal.[14] Thus, the exercise of malaria control on these islands had fortuitously furthered filaria control.

The epidemics of dengue fever on New Caledonia, Efate, Espiritu Santo and

[14] Rieber et al. Studies on Vectors of *W. bancrofti*, Newsletter No. 26, July 1945 and ComSoPac Occasional Papers No. 1, Sept. 1945 and No. 2 Oct. 1945, Headquarters Malaria and Epidemic Control, South Pacific Area.

Tualagi-Florida are noted above. Local malaria control groups had given repeated warnings of the potential hazard of tin can dumps and other breeding places of the dengue transmitting mosquito, *Aedes aegypti* (L). With the outbreak of these epidemics, the organization was given adequate authority, personnel and equipment to cope with the problem. As a result there was no dengue outbreak in 1944 on any base except New Caledonia where it was held to small proportions.

The outbreak of tsutsugamushi disease (mite-borne typhus) on Bougainville led the local malaria control organization to assume responsibility for protective measures including impregnation of clothing with dimethylphthalate. Study of this disease and its control was aided by the arrival of an advance unit from Naval Medical Research Unit No. 2 (11) which was attached to the Base Malaria and Insect Control Group.

Rodent Control was undertaken both to prevent economic loss from rats and to prevent the spread of epidemic diseases which were harbored or transmitted by rats or their ectoparasites. An officer qualified as a mammalogist or with civilian experience in rodent extermination was appointed as rodent control officer and attached to the malaria and insect control group at each large base. An adequate number of enlisted men, equipment and transportation were provided. A manual was prepared and men from each military unit on the island were trained in the technique of rodent extermination and their work was then supervised. Fumigation of ships for rats was done on request.

3. Procurement and Assignment of Personnel

Table V summarizes the sources and number of personnel available to the South Pacific Malaria and Insect Control Organization as of 15 May 1944. The technically trained personnel comprised medical officers, entomologists, parasitologists, sanitary engineers, and enlisted personnel of the control and survey detachments. They formed the Base and Division Malaria and Insect Control Groups and were the technical and administrative nucleus of the entire organization. As of May 15, 1944, this personnel comprised 128 officers and 643 enlisted men, divided as follows: Army—452; Navy and Marine—282; New Zealand—37.

a. Technically trained army malaria control personnel was provided by the War Department in 3 categories: Malariologists (medical officers), Malaria Survey Detachments and Malaria Control Detachments.

Army malariologists arrived as casual officers. Almost all of these officers had taken the course in Tropical Medicine at the Army Medical School and the majority had had field work at the army school in Florida or Panama. They were attached to Headquarters, Service of Supply, South Pacific Area, and then ordered on detached service to the various bases and divisions. There were 21 army malariologists in the area; 2 Lt. Colonels, 8 Majors, and the remainder Captains. One army malariologist was on the Area Malaria Control Staff, 6 were senior base malariologists, 6 were division malariologists, 1 was assigned to the Office of the Chief Surgeon, USAFISPA, 1 to Headquarters XIV Corps, and the remainder acted as assistant base malariologists.

Army Malaria Survey Detachments consisted of an entomologist, a parasitologist and 11 enlisted men, with 5 vehicles[15] and adequate laboratory equipment for all ordinary entomological and parasitological survey work. Army Malaria Control Units consisted of a sanitary engineer and 11 enlisted men and were authorized 8 vehicles and light engineering equipment.[15] Officers were well qualified, and enlisted men were usually of high calibre and rapidly became competent.

The army control and survey detachments were small commands and were transferred or assigned intact. There were 17 Malaria Survey Detachments and 20 Malaria Control Detachments within the area, as of 1 June 1944. One addi-

TABLE V

Malaria and insect control personnel—SPA

15 May, 1944

DESCRIPTION	SOURCE		NUMBER
Technically Trained Personnel*	War and Navy Depts. Special Survey and Control Detachments for Tropical Disease		771
Malariologists, Entomologists, Parasitologists, Sanitary Engineers, Rodent Control Officers and Trained Enlisted Personnel			
Skilled Labor			
Operators of Heavy Equipment	Navy Construction Battalions		634†
Dynamite crews	Army Engineer Corps		
Flume crews, etc.			
Unskilled Labor			3002
Medical Sanitary Companies	War Department	936	
Troop Antimalaria Details	Troop Units	1479	
Natives	Local Government Agency	587	
Total			4407

* Base and Division Malaria and Insect Control Groups.

† Average figure for 6 months, December 1943–June 1944.

tional survey unit and 2 control units had been trained and staged for the South West Pacific Area.

b. Navy malaria control personnel was procured through the Navy Department either from the Malariology School of the Naval Medical School, Bethesda, Maryland, or from Navy replacement pools or other organizations within the South Pacific. The usual Navy malaria control team consisted of one officer, an entomologist, and 3 to 5 enlisted men. Larger teams of 3 officers (malariologist, entomologist, parasitologist) and 12 enlisted men were supplied to Marine Divisions. An engineer for this group was provided with the sanitary section of the attached construction battalion, see below. Enlisted men from Bethesda were well trained in laboratory diagnosis and in elementary field procedure.

[15] TO/& E No. 8-500, 13 May 1944.

Several Navy officers experienced in rodent control were obtained from organizations in the South Pacific. Navy warrant and Hospital Corps officers were also secured locally to administer malaria control personnel and supplies on larger bases.

The size of a base unit was established by local requirements, and no predetermined limitation was set. For this reason Navy malariology teams were broken up freely and fitted to existing needs for expansion or replacement in mixed Army-Navy or all-Navy groups.

c. Skilled Labor and Heavy Equipment. Skilled labor for malaria control work included dragline and bulldozer operators, dynamite experts, carpenters, and welders to make flumes and culverts. Such skilled personnel and heavy equipment were obtained chiefly from Naval Construction Battalion personnel, and in small part, from the Army Corps of Engineers.

The formation of Sanitary Sections in all Naval Construction Battalions for use on malaria control work was authorized by a series of directives.[16] These directives ordered formation in each Naval Construction Battalion of a sanitary section of 110 enlisted men plus a specified list of equipment for work on malaria and epidemic control projects under the direction of Base and Division (Marine) malariologists. Equipment assigned to each sanitary section included 1 dragline crane, 1 tractor with bulldozer blade, and 7 trucks. These directives made available to malaria control a potential total force of over 2000 men and more than 20 bulldozers, 20 dragline cranes and 140 vehicles from the 20 or more Naval Construction Battalions that were on malarious bases. Actual compliance with these directives furnished about 500 SeaBees, 10–15 bulldozers, and 8–12 dragline cranes daily for work on malaria control projects during the 8 month period, November 1943 to June 1944.

Despite outstanding work by many of these battalions, compliance with these directives was usually delayed and incomplete. Work often was done too late to forestall an initial outbreak of malaria and seeding of troops. This delay was due to high priorities for airfields, roads, harbor and storage facilities. Requests for diversion to malaria control of 10 per cent of men and equipment often seemed unreasonable to the officers responsible for major construction projects. This early attitude was fostered by the routine use of suppressive atabrine which temporarily hid the full extent of seeding with malaria. Furthermore, certain faults were inherent in the sanitary section of the construction battalion as originally conceived. Construction battalion personnel comprised for the most part rated men and highly skilled labor, the number of seamen decreasing with every month overseas. It was wasteful and damaging to morale to use skilled labor for unskilled manual work. Wherever possible the use of skilled construction battalion labor was limited to the use of heavy equipment and to other skilled jobs while unskilled manual work was done by native labor.

[16] a. VCNO ltr. OP 30 Pz-MP (SC) P 2–3, serial 0613830, dated 9 July 1943;
b. BuDock Directive, PacDiv Serial 948, YDI-me, dated 17 May 1943;
c. ComSoPac Serial 01227, dated 31 July 1943; and
d. ComSeronSoPac Serial 0744B, dated 6 August 1943.

In May 1943, before receipt of the above directives, the need for large scale mosquito control work on Guadalcanal became so urgent that the entire 63rd Naval Construction Battalion was ordered by ComSoPac to malaria control work at that base. The personnel of this battalion rapidly became acquainted with malaria control problems and techniques and accomplished an extraordinary amount of semi-permanent control work over the entire base.

The use of Army Engineers for Malaria Control was authorized[17] as follows: "The Corps of Engineers is charged with the responsibility for the execution of mosquito control work on real property. This includes such measures as drainage, filling, larvicidal programs and screening." The number of Army Engineers Corps troops in this area was small, as compared with Naval Construction Battalions. The use of such troops for malaria control projects was subject to the same delays encountered with Naval Construction Battalion Sanitary Sections with the added handicap that no set per cent of Army Engineer troops was directed to do malaria control work. A few Engineer Corps troops did excellent work on insect control projects but the total was small.

The practice begun during 1944 of submitting consolidated estimates for all base malaria control projects to the Commanding General, with the request that these projects be assigned to heavy equipment units, resulted in division of these projects between Army Engineer Units and Navy Construction Battalions. Such projects were well prosecuted.

In summary, the malaria control organization rarely succeeded in so presenting the need for heavy equipment for mosquito control as to secure its accomplishment in the early days on a base. Eventually, an adequate amount of skilled labor and heavy equipment was made available on all bases, but only after delays which contributed to seeding of troops with malaria and dengue and to great loss of man days and efficiency. On most bases such work was delayed more than 6 months after occupation. Only on Emiru Island in the St. Matthias Group, the last operation in this area, was a significant amount of heavy equipment made available for mosquito control work within 3 months of occupation.

A large share of semi-permanent work was done with borrowed equipment which was operated by personnel of malaria control detachments and medical sanitary companies. Malaria Control personnel on Guadalcanal operated an average of 10 bulldozers, 2 draglines and several disc harrows throughout 1944, and similar personnel on Santos and Bougainville operated about half this amount of equipment. These experiences led to a recommendation to the War Department, approved by Headquarters, Services of Supply, South Pacific Area, to add such earth moving equipment to the table of equipment of medical sanitary companies. Only by some such plan would it have been feasible to accomplish semi-permanent control work during the early months on a new base.

d. Unskilled Labor. Unskilled labor was used for oiling, for hand clearing and ditching, and for other details. It was obtained from 3 sources: army medical sanitary companies, troop unit antimalaria details and natives.

[17] AR 100–80, as quoted in par. 2, WD Circular No. 223, 21 September 1943.

Each Army Medical Sanitary Company consisted of 3 white officers and 109 colored enlisted personnel. (One Sanitary Company had colored officers.) These companies provided their own messing facilities and were authorized[18] 9 vehicles and other suitable equipment. They were assigned to Island Commands and were employed as directed by the malariologist in conjunction with antimalaria work. There were 8 Medical Sanitary Companies used only for malaria control within the South Pacific Area as of 1 June 1944, located as follows: 4 companies on Guadalcanal; 1 each on Russell Islands, Munda, and Bougainville; and 1 divided company with a platoon at Green Island and a platoon at Emiru Island. They rapidly developed an understanding of the problems of malaria control and facility in necessary procedures. Enlisted men who showed aptitude were trained in the operation and maintenance of heavy equipment, in dynamite work and in mosquito survey work. These troops were of great value as a constant source of experienced labor.

Troop unit antimalaria details[19] were charged with oiling, minor drainage work, and other control measures in their bivouac area. These details consisted of 3 men from each company or similar unit and were the backbone of all insect control work.

Natives were employed on nearly all bases. The decision to utilize this source of labor was made early in the campaign with the knowledge that natives constituted a potential seed bed of malaria and filariasis. The malaria control organization attempted to minimize this health hazard by segregation of natives and by other means described under section on malaria control measures. The Melanesian natives in the New Hebrides were controlled by the Condominium Civil Government; those in the Solomon Islands by the British Solomon Islands Protectorate. Natives were recruited from outlying islands or areas under Colonial government supervision and allotted to the various military bases. Only healthy adult males (except at Bougainville) were accepted. A fixed contract as to period of hire, wages, food, quarters, and hours of work was established by the Colonial government. Native laborers in the Solomons were formed into semi-military organizations under white officers. This labor was paid by the government of the British Solomon Islands Protectorate and furnished to U. S. Forces without charge as one of their contributions to the war effort. It was agreed that the U. S. Government would provide such native labor with quarters, rations and certain other benefits and that these supplies would not be charged against the British Solomon Islands Protectorate under lend-lease. On most islands the natives were under the immediate supervision of an Australian, New Zealand or other labor corps officer. Natives worked in sections of 25, each with its own native sergeant. Transportation to and from work was provided by the military activity using them. The total number of imported Melanesian laborers on all bases was over 6000 in 1944. About 600 or 10 per cent of these natives worked daily on malaria control during the period of maximum activity in the theatre.

[18] T/O & E No. 8–117, 13 May 1944.

[19] See par. E4 below.

4. Supplies and Equipment

There were acute shortages of all antimalaria supplies and equipment in 1942, of which the most important were atabrine, mosquito repellent, insecticide and knapsack sprayers. In this early period the area malaria control organization advised on allowances and was responsible for the establishment of quotas and distribution of those items in which shortages were acute. Excerpts from the pertinent directive follow:

HEADQUARTERS SERVICES OF SUPPLY

AG 729.5 (5-11-43) APO 502
13 May 1943

Circular ISSUE OF INSECTICIDE

No. 15 PEST CONTROL SUPPLIES AND EQUIPMENT

"1. Control, procurement, distribution and issue of insecticides, pest control supplies and equipment for all Armed Forces located in the South Pacific Area has been assigned to the Army Services of Supply by ComSoPac.

"2. Service Command Quartermasters . . . in cooperation with the Base Malaria Control Officers, will receive, store, and distribute the above supplies to all Armed Forces at each base. Navy Supply Officers, Marine Quartermasters and New Zealand Supply Officers may obtain their stocks in bulk from Base or issue Service Command Quartermasters at each Base, by requisition.

"5. The use of insecticide and insect repellents within the South Pacific Area will be governed by instructions issued by each base malaria control officer."

The inclosures to this circular fixed allotments for pest control supplies and equipment. Supplies were distributed to Island bases by automatic issue as they became available. This arrangement worked well. At first it was necessary to lower the quotas of certain critical items below the allowances given in Circular 15. The policy was to curtail all rear base quotas in an effort to assure adequate supplies to the forward and combat bases. The supply of freon aerosol dispensers is an example. This item became available in significant quantities about September 1943. The area malaria control staff recommended that the quota for troops in the Southern Solomons be fixed at 100 dispensers per 1000 men per month and that only troops moving to combat areas in the Northern Solomons receive a full allowance, which at that time was 225 dispensers per 1000 men per month. Supplies of all items except DDT were adequate by March 1944 and no further quota restrictions were necessary.

Acute area shortages of atabrine both for treatment and suppression were encountered during 1942. Early in 1943 an adequate quantity of atabrine was available and a system of priorities was no longer necessary. Quinine was used extensively for suppression and clinical treatment during 1942 and early 1943, but its use waned as the value of atabrine was demonstrated.

Transportation was often a serious problem. Each Malaria Control Group was responsible for a territorial coverage of about 20 square miles, often in the shape of a long narrow beachhead. In addition to distributing their own survey and control crews to all parts of this territory, most groups transported 50

to 100 native laborers to and from work each day and hauled labor details. They also did power spraying, hauled gravel and did other work requiring vehicles. The increased number of vehicles which were finally authorized for malaria detachments and for medical sanitary companies were adequate. A special directive provided transportation for malariologists.

The majority of all personnel lived in pyramidal tents; others in prefabricated huts. Buildings were required for offices, laboratories, classrooms, store houses and workshops. Quonset huts and other material for these buildings were supplied in 1943 through Navy channels. Subsequently the Island Command at most bases provided additional housing.

E. BASE OR ISLAND ORGANIZATION AND PROCEDURE

1. The Work of the Malariologist

The legal basis for the work of the island malariologist has been described.[20] By these directives the senior malariologist at each base eventually was made directly responsible to the Island Commander for the formulation of a program of control applicable to all forces, Army, Navy, Marine and Allied, and for recommendations to make this program effective. The commanding officer of each subordinate organization was responsible for all malaria control activities within and adjacent to his bivouac site. Reports and recommendations of the senior base malariologist were submitted directly to the Island Commander, who, in turn, required the subordinate commander to carry out prescribed control measures. This chain of command was unusual in that it did not conform with the ordinary channels through the Commanding Officer of Service Command or through the Commander, Advance Naval Base. The proper choice, of channel was uncertain with a joint Army-Navy malaria control organization which might be headed by an Army or a Navy malariologist or by both at successive periods. This joint organization, moreover, supervised malaria control projects which involved both services and made inspections and reports on the malaria discipline of all forces. Direct access to the Island Command was authorized to obviate these difficulties and because the Island Command had a greater ultimate responsibility to reduce the island malaria rate than had any subordinate command.

The organization of the Army-Navy malaria control personnel on each Base is also shown by Chart II. A mixed Army-Navy group was developed on most islands. The variable size of the Navy units was particularly advantageous for small bases where only one or two officers and a few enlisted men were needed and where the army units of fixed size were too large. The service distribution of the technically trained personnel is given in Table VI, and of the labor in Table IX. The efficiency and economy of this joint use of personnel provides a stimulating chapter in combined service organization.

Chart III, Guadalcanal Malaria Control Organization, is presented as an example of organizational development on islands large enough to require 2 or

[20] ComSoPac 002263 and Memo Hq. USAFISPA quoted in Sec. D.1.

CHART II. BASE ORGANIZATION AND COMMAND CHANNELS

Joint Army-Navy malaria and insect control

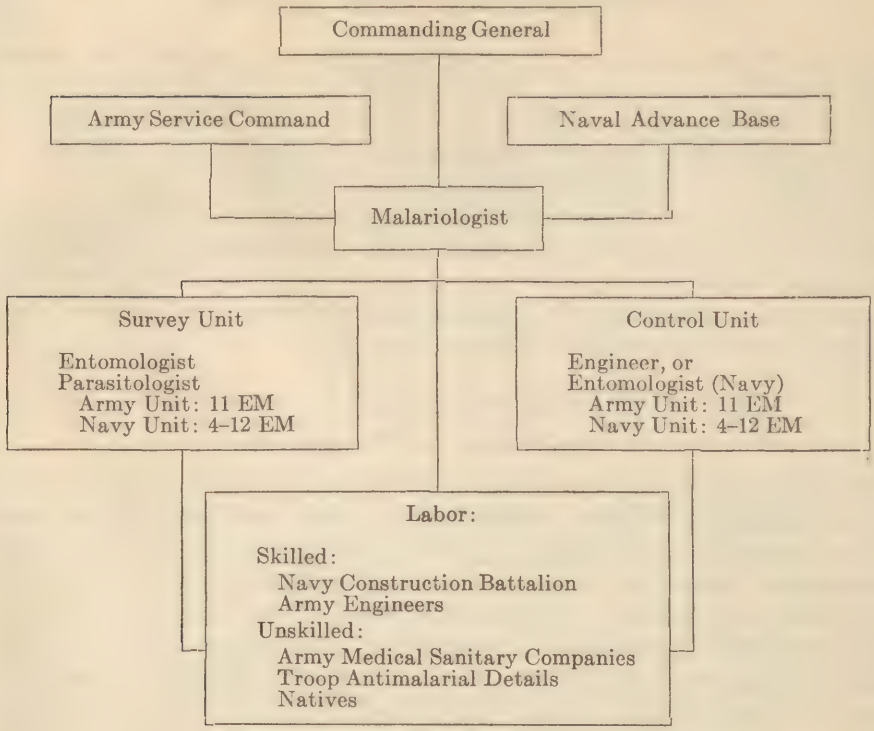


TABLE VI

Base malaria control personnel, South Pacific area

(As of 15 May 1944)

BASE	ARMY		NAVY		TOTAL
	Officers	Enlisted	Officers	Enlisted	
Hq. MalConSoPac	2	1	3	3	9
New Zealand	1	0	0	4	5
New Caledonia	7	47	3	14	71*
Efate	4	22	2	11	39
Espiritu Santo	2	11	17	40	70†
Guadalcanal	31	179	2	20	232‡
Tulagi-Florida	0	0	5	25	30
Russell Islands	0	0	5	28	33
Segi, New Georgia	0	0	1	4	5
Munda	5	22	3	12	42
Vella Lavella	0	0	1	14	15
Treasury	0	0	2	10	12
Bougainville	6	33	1	8	48
Green Island	1	0	2	14	17
Emiru	4	22	2	10	38
Total	63	337	49	217	666

* Includes 50 staging personnel (Army).

† Includes staging personnel (Navy).

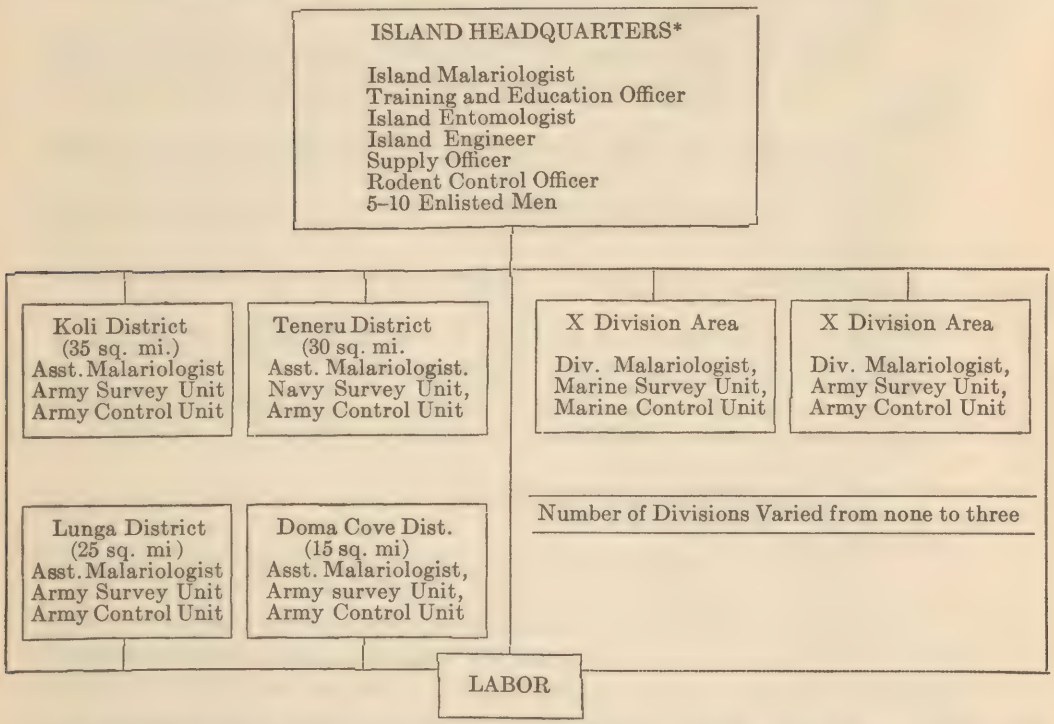
‡ Includes 113 staging personnel (Army).

Note: This table comprises technically trained personnel only. Divisional personnel are omitted. See Table IX for distribution of labor personnel from various services.

more malaria control groups.[21] The Island headquarters was not provided for by any Table of Organization but developed to fill a need for overall supervision on larger bases. Modifications of the headquarters section, diagrammed in Chart III, were established on Efate, Espiritu Santo, New Georgia, and Bougainville.

The malaria control personnel on most bases formed a joint Army-Navy group who lived under one roof and worked together in one area. Two-thirds of the groups were attached to Army or Navy hospitals for rations, one-third to

CHART III. GUADALCANAL MALARIA AND INSECT CONTROL ORGANIZATION



* No authorized table of organization for this headquarters. Supply Officer and Rodent Control Officer are Navy personnel, others are Army.

Navy Advanced Bases or Army Service Commands. Three groups set up independent housekeeping with a Medical Sanitary Company assigned to malaria control work. This had distinct advantages, among which was a time for messing which was most advantageous for field work.

The position of the malariologist in this organization was an ambiguous one which can be explained best by saying that he was a staff officer whose duties often required the assumption of command responsibility. This was evident in

[21] The term Malaria Control Group is used to designate a working organization comprising a malariologist, a malaria survey detachment and malaria control detachment.

his relations with assistant malariologists, and with personnel of survey detachments, control detachments and sanitary companies. He selected their locations, directed their work and initiated or approved recommendations for promotion. This assumption of command responsibility functioned well because of a general willingness to cooperate and because the high command fostered such a situation by directives quoted above which made the malariologist responsible for all insect control activities on a base. However, the malariologist had no legal command authority over the malaria detachments and medical sanitary companies which were small independent commands. In a long range program this officer should have command authority corresponding to his responsibility.

The duties of the malariologist included:

a. Planning an effective program of mosquito control utilizing the advice and assistance of specialists, the entomologist, the parasitologists and the engineer.

b. Integration of the work of the survey detachment, the control detachment and labor.

c. Estimation of need for and requisition of personnel and supplies to execute his program.

d. Development of an effective malaria training and educational program (Sec. F.).

e. Preparation of directives pertaining to malaria discipline and the making of spot inspections for violations of malaria discipline.

f. Consultation and recommendation in regard to the selection of sites for camps, airfields, bivouac and maneuver areas.

g. Segregation of natives.

h. Recommendations concerned with the institution and discontinuance of suppressive medication.[22]

i. Supervision of disinsectization of airplanes and ships and other measures to prevent the dissemination of disease.

j. Preparation of reports of the malaria situation on his base or in his division area, including especially statistics regarding malaria incidence, status of malaria discipline, entomological and climatological data, work of control units, activities of the training program, status of anti-malarial supplies and of personnel engaged in control work, recommendations.

The malariologist, in execution of these duties, provided frequent, up-to-date estimates of the insect-borne disease situation on his base or in his division area. This information was obtained prior to the occupancy of a new base from the literature, from colonials with pre-war knowledge of the area, and from data gathered by Army and Navy intelligence sections. The study of rainfall figures and aerial mosaics was valuable in estimating probable breeding sites. More reliable information was obtained after occupancy of an island from the entomologist's surveys of mosquito populations, from data of malaria incidence in troops and natives, and from the engineer's reports of existing control activities

[22] ComSoPac Serial 02259 Nov. 1944.

and future requirements. He formulated an effective control program based on these reports, the advice of his specialists, and his knowledge of the tactical and supply situation. The first work was done where troops were concentrated. Small, isolated outposts were furnished with sprayers and other supplies but were required to do their own antimalaria work during this early period. Speed in instituting control measures was most important in occupying a new base. Initial surveys were done rapidly and more thorough work came later. A larvicidal program and other temporary work, such as clearing of paths to facilitate oiling, was usually initiated coincidently with the first survey.

The initiation of semi-permanent work depended on the size of troop population to be protected, the period the area was to be occupied, and on available labor and equipment. As soon as surveys were completed a list was prepared of semi-permanent control projects with detailed estimates of labor and equipment, see Paper III. These projects were listed in order of priority and were initiated directly if they were within the scope of the malaria control personnel under the jurisdiction of the malariologist. Larger projects requiring special equipment and labor were submitted through proper channels to the Commanding General for approval and for assignment of the needed equipment and personnel. These projects competed with other high priority work such as road building, airfield construction, and erection of hospitals. Presentation of a project had to be clear, concise, specific and had to include an adequate justification for priority.

The need for continuous integration of the work of the survey and of the control units was recognized rapidly. Apparently the original plan envisaged a survey unit that would land in the early days of occupancy of a base, would determine the problem and lay down a plan of operation for the control unit which would arrive at a later date. In war time practice, survey and control work were initiated simultaneously and continued to be interdependent. It was a part of the early experience of newly arrived entomolgists that survey work was of immediate military value to the extent that it was translated into control of insects. Likewise it was the daily experience of engineers that their efforts to control insect breeding were much more effective if closely correlated with the work of the entomologist and the parasitologist. This team work between survey and control personnel was achieved by the joint use of living quarters, office and laboratory space and particularly by the efforts of entomologists and engineers in their daily field work, see Sec, D 3 of Paper III. The malariologist was in constant touch with these units and with his labor groups to assist in the solution of their supply and personnel problems. The effective integration of the work of these various units was one of the chief measures of his success.

Supply problems and many minor administrative problems often required much of the time of the malariologist. On the larger bases this work frequently was delegated to Navy warrant officers who were assigned for that purpose. Storehouses (fig. 1) were built and inventories of anti-malaria supplies in the quartermaster, ordnance and engineer dumps were maintained. Guadalcanal

became a supply base for all malaria and insect control groups in the Northern Solomons.

Further discussion of the duties of the malariologist are found in other sections, i.e., Sec. F. The Training and Education Program.

FIG. 1. CORNER OF STOREHOUSE FOR INSECT CONTROL SUPPLIES ON GUADALCANAL

TABLE VII

Entomological section of survey detachment——example of personnel organization

DESIGNATION	NUMBER	DUTIES
Officer	1	Entomologist in charge of entomological activities
Senior N C O	1	Direct supervision of both field and Laboratory work
Laboratory men	2–3	Map making, mosquito population records, rainfall records, care and identification of specimens brought to and reared in insectary
Field men	5–8	Field men survey 3–5 square miles per man. A 5 man crew covers an area of 15–25 square miles

2. The Malaria Survey Detachment

The malaria survey detachment consisted of two officers and eleven enlisted men, all technically skilled, and charged with entomological and parasitological work to aid the control of malaria and all other insect borne diseases. Table VII shows the organization and duties of the entomological section of the survey detachment.

The entomologist and his enlisted men furnished information about the breeding of mosquitoes and other insects, their biology and relations to disease. This information was always accompanied by recommendations as to specific control measures. This work was continuous and was recorded on maps and other forms so as to give a clear and continuous check on the effectiveness of control. The preparation of adequate maps from aerial mosaics and ground inspection was fundamental to insect control work and was one of the responsibilities assumed by the entomologist.

The parasitological section of the survey unit comprised 1 officer, a parasitologist, 1 senior non-commissioned officer in charge of the parasitology laboratory and 1 to 3 enlisted laboratory technicians who provided information about parasitic diseases of military importance. They furnished information about the incidence of malaria and other parasites in natives, in our own troops and

TABLE VIII

Malaria control detachment——example of personnel organization

DESIGNATION	NUMBER	DUTIES
Officer	1	Engineer, SnC., or H-V (S) in charge of all control activities
Senior NCO	1	General supervision, asst. to Engineer
NCO	1	Contact with troop oiling squads and work details from Sanitary Company
NCO	1	Contact with work crews of heavy equipment units; with level and transit crews
NCO	1	Clerk
NCO	2	Supervisors of native crew
NCO	1	Utility repair man to service hand sprayers, power sprayers and dusters for all organizations
NCO	1	Vehicle Dispatcher and repair man
Pfc or HA/2c	1	Truckdriver, dump truck
Pfc or HA/2c	1	Truckdriver, powersprayer
Pfc or HA/2c	1	Truckdriver, general

Japanese prisoners and recorded this knowledge so as to aid both the planning and the evaluation of control work.

Both the entomological and parasitological sections participated actively in the training and education program and in other aspects of the work. Details of the entomological and parasitological problems and methods in the South Pacific Area are presented in papers III and IV.

3. The Malaria Control Detachment

The name of this unit, like that of the survey detachment was a misnomer because its work embraced the planning and execution of all control activities directed against not only malaria, but also dengue, filariasis, tsutsugamushi disease, fly borne diseases and occasionally against pests. After moving from the South Pacific to other areas many of these units were used in the control of Japanese B encephalitis, schistosomiasis and other diseases. The usual organization of a malaria control detachment is shown in Table VIII.

The commanding officer of a control detachment was an engineer and was responsible for planning, execution and maintenance of all insect control measures based on the findings of the survey detachment; for supervision and correlation of all labor and equipment for this work; and for maintenance of suitable records to give a continuous and clear picture of control activities.

The enlisted personnel performed a variety of duties, according to the local situation. These men were most economically and efficiently employed as supervisors. Occasionally, on large bases, an entire control team was made responsible for a special project such as work on flume and culvert maintenance. Additional enlisted personnel were assigned to work with dynamite or bangalore torpedo

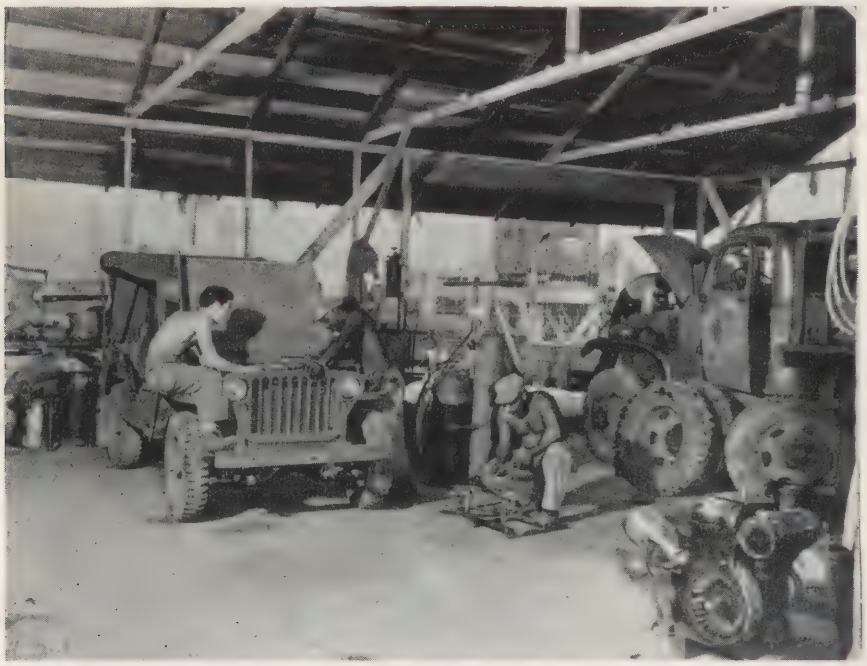


FIG. 2. MOTOR REPAIR SHOPS OF THIS TYPE WERE OPERATED BY MALARIA CONTROL HEADQUARTERS ON LARGER BASES

ditching crews. Men were trained to run bulldozers, operate draglines, and other heavy equipment. On islands where airplane spraying of DDT solutions became an important control measure, crews of 1 to 6 men were assigned to mix DDT solutions and to service the spray apparatus installed in the planes.

A motor repair shop (fig. 2) was organized on many islands in order to avoid delay in obtaining service at regular army motor repair units. Thus, on Guadalcanal where the malaria control organization had over 100 vehicles to keep in service, a repair shop was staffed by mechanics in the local organization and was equipped to do all types of motor repair work except rebuilding jobs. A welding shop was established for making flumes and for repair work.

Table IX shows the average number of laborers available for the work of the

malaria control units during the period of 6 months from December 1943 to June 1944. The engineer was responsible for the work of these laborers except that of the troop anti-malaria details. Thus, on the larger bases, each engineer had from 100 to 250 men, exclusive of troop units, working under his general supervision. There were 4 engineers on Guadalcanal, so the figure for that base was divisible by 4 to obtain the labor available to each engineer.

4. Troop Unit Anti-Malaria Organization

From the first, antimalaria details were expected to do the larvicidal work in their own areas. The assignment of men to oiling details in 1942 and the early half of 1943 was irregular and depended on personal arrangements between the

TABLE IX

*Labor available for work of control unit**

BASE	AREA TO BE CONTROLLED	NUMBER OF LABORERS					
		Base control unit	Seabee or Army Eng. unit	Med. San. Co.	Natives	Troop antimalaria details	Total
	sq. miles						
Efate	39	15	12	0	95	40	162
Espiritu Santo	40	33	10	0	0	350	393
Guadalcanal†	110	55	355	292	250	350	1302
Tulagi-Florida	9	18	35	0	37	70	160
Russells	15	15	42	117	40	150	364
Munda	20	18	35	117	75	80	325
Bougainville†	50‡	22	10	117	80	150	379
Green Island	15	5	12	65	0	125	207
Emiru	30	15	60	50	0	60	185
Vella Lavella	20	10	33	0	10	?	53
Treasury†	7	4	30	0	0	104	138
Total		210	634	758	587	1479	3668

* Average figures for six months, December 1943 to June 1944 (except Emiru which was occupied in March 1944).

† Omits divisional units.

‡ Controlled area increased from about 30 to 50 square miles during above period.

island malariologist and each commander. In February 1943 the Commanding General on Efate ordered the formation of an anti-malaria detail in each company or similar unit. In April 1943 a division commander ordered approximately 1 per cent of his command to fulltime malaria control work. In May 1943 the Commanding General on Guadalcanal ordered that 2 per cent of the command strength be diverted to malaria control activities. In July 1943 a malaria control group was attached to Corps Headquarters for the initial landings in the New Georgia campaign. Specially qualified medical department personnel, hereafter described as Malaria and Insect Control Groups, were attached to Marine divisions in July 1943 and to Army divisions[23] in September 1943. In

[23] AG 370.5 Hq USAFISPA, 29 September 1943.

September 1943 an area wide directive[24] ordered the formation of a mosquito control squad in every battalion. These were later consolidated in a single directive[25] which ordered the formation of an antimalaria detail in each company, battery or similar unit. This detail consisted of 1 non-commissioned officer and 2 enlisted men per infantry company or a proportionate number for other units. In non-medical units these details were made up of non-medical personnel. These details were responsible for all insect control work within the region occupied by their units and their work was checked by technicians from the base or division malaria survey detachment described above.

These anti-malaria details worked effectively in all situations except those of front line combat. It was not only impossible for most anti-malaria details to do antimosquito work under combat conditions, but this personnel was as fatigued as their comrades at the end of the combat period and so further postponed this work. To remedy this situation, temporary spray teams were formed in combat regiments and are described below.

5. Division Malaria and Insect Control Organization

The Division Malaria and Insect Control Group comprised the division malariologist, a malaria survey detachment and a malaria control detachment totaling 4 officers and 22 technically trained enlisted men. This group was attached to the division over and above its established allowance for medical department personnel. They performed the same functions for the division as did the base malaria and insect control group for each island base. The detailed duties and responsibilities of the malariologist, the entomologist, the engineer, and the parasitologist were similar to those outlined above, with the additional duty of providing anti-malaria protection during the periods of active combat. This resulted in less emphasis on specialization and more emphasis on flexibility, with every man trained to aid in all phases of a simple antimosquito program.

It was the duty of the division malariologist to provide plans for the control of malaria, dengue, mite-borne typhus, and other insect-borne diseases during a period of active operation. Several plans were prepared contingent on such factors as advance information of medical problems, the anticipated speed of the operation and whether the division was to act as a compact unit or was to be spread out over a wide front as separate regiments or battalions. The final plan, selected from several prepared in advance was determined by the particular military situation.

An important feature of all such plans was the provision for a pool of trained men to do temporary insect control work behind the lines during combat periods. This pool of personnel was obtained by drawing 1 man from each antimalaria detail and adding a technically trained nucleus from the attached survey and control detachments. In most plans this personnel was split into 4 temporary spray teams, 1 team attached to Division Headquarters and 1 team to each of the 3 regimental Headquarters. These temporary spray teams gradually im-

[24] ComSoPac serial 01619, dated 13 September 1943.
[25] ComSoPac Serial 02158, dated 19 October 1944.

proved in operation and functioned well for combat units which staged in the South Pacific for the Peleliu and for the Okinawa campaigns. The temporary spray team went ashore with the division or regimental headquarters to which it was attached and began work. Fly control was done by spraying dead bodies with 5 per cent DDT solution or 1 per cent sodium arsenite solution. Straddle trenches, pit latrines and other sources of fly breeding were treated similarly. Mosquito control measures were carried out around headquarters, medical facilities, supply dumps and along communication lines. Details of this work are given in Appendix I.

F. THE TRAINING AND EDUCATION PROGRAM

The training and education program was planned to reach every officer and man in the area on a level consistent with his responsibility. This program fell into two parts, one the work of the area headquarters staff who developed the necessary directives, provided manuals, posters and other educational aids and conducted a small area training center; and the other, the work of base and division malaria control groups who directed the mass education program.

1. The work of the area staff was headed by the Area Training and Education Officer. The area staff prepared six pocket size manuals, three on malaria and one each on dengue, filariasis and rodent control. The three manuals on malaria were written respectively for medical officers, for line officers and for enlisted personnel. About 500,000 copies were printed locally to provide one for every officer and man in the area. The area staff included an artist who produced over a two year period, 15 posters, a monthly pin-up calendar and a weekly cartoon for the Sunday edition of the local mineographed paper. "Malaria Moe" and the Frank Mack versions of a pin-up girl and of an anopheles mosquito were found in nearly every tent and quonset hut in the area. Posters were reproduced in numbers to supply one large and one small size for every two hundred men. One calendar was printed monthly for every five men, Fig. 3.

A library of malaria control films was obtained and circulated to all base and division groups who arranged for command showing of the more important ones. Only two films were considered adequate, a "Snafu" film on malaria and a film produced by the Army Air Corps, TF1-3343. Other films were out-dated, were too technical or were not accurate. Adequate films were not to be had on dengue control, on filariasis or on rodent control. Yet such excellent results were obtained from the few films that were available that it is to be hoped that more and better training films will be prepared for these subjects.

A monthly news letter was found to be a most successful method of disseminating current information to malaria control officers, hospitals, base and division surgeons.

An Area Training Center in Malariology and Other Insect-borne Diseases was established first at Efate and later at Espiritu Santos, depending on the current location of Area Malaria and Insect Control Headquarters. It began late in 1942 with small classes of 3 to 5 officers for 2 week periods. The students at this school included all newly arrived malariologists and such troop unit malaria

control officers as could be spared from their organizations. The school was located on the grounds of a large hospital which had a high census of patients ill with malaria and other tropical diseases and who were available for clinical and parasitological study. The medical staff of the hospital aided the area malaria control staff in the teaching program. Adequate parasitological and entomological collections were built up and a small but good library was obtained.

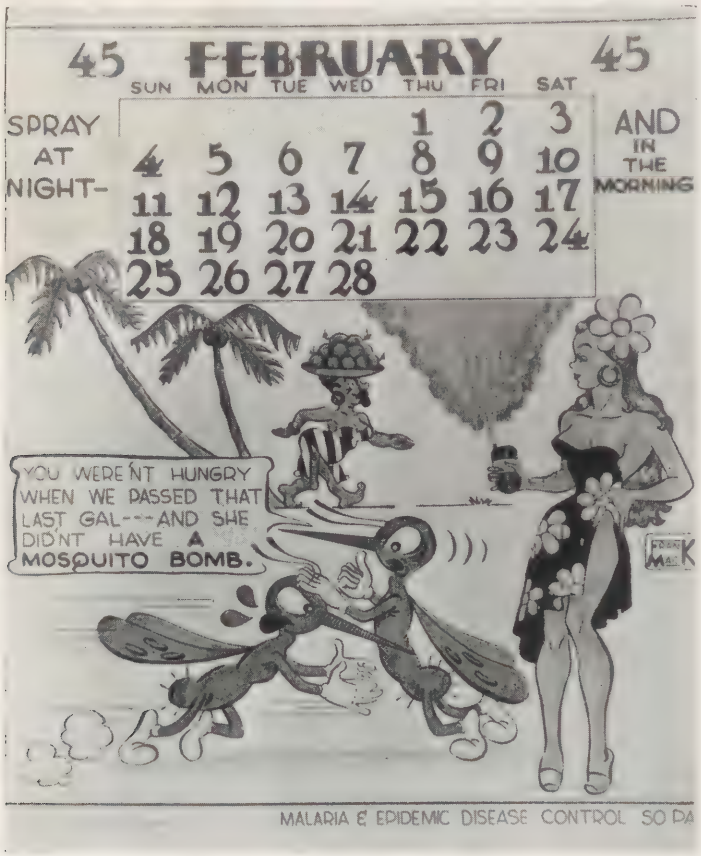


Fig. 3. Pin Up Calendars in Four Colors Were Distributed at the Rate of One Per Ten Men

Thirty malariologists, or more than two-thirds of those who worked in the area, attended this school as did a larger number of troop unit malaria control officers. A small number of entomologists and parasitologists were present at these courses, their work being arranged to give them more time in their specialty and less clinical work.

The daily schedule included ward rounds and clinical conferences, parasitology and entomology laboratory, a lecture and 2 to 4 hours of field work. The curriculum emphasized current problems in the area and included a study of the malaria

rates of each base, division and other adequately observed group. The early attempts to demalarialize large bodies of troops and the later policy to continue atabrine in heavily seeded units during their rehabilitation was studied. Practical experience was obtained with the work of the survey and control detachments and with their records and report forms. Administration and supply problems were discussed with the Area Administrative Officer. The history of atabrine, particularly as a suppressive drug, and the implications of current work on atabrine serum levels were considered. The urgent need for better methods to prevent the spread of malaria to non-malarious bases was stressed. Students took an active part in the local work of the training and education program.

2. The training program on each island or base was divided in three parts, an apprenticeship system for newly arriving personnel of malaria control and survey detachments, a short school for troop unit antimalaria details and a simple educational program for every man in the area.

a. The apprenticeship system was devised to meet the needs of incoming malariologists, entomologists, parasitologists, engineers and the men of their detachments, few of whom were experienced in the problems peculiar to the South Pacific area. This apprenticeship period lasted 1 to 3 months. The teaching staff consisted of the entire personnel of a veteran group (Malariologist, malaria survey and control detachments and labor units) and the curriculum was the daily work of this established group plus a planned training program.

The apprenticed or staging malariologist observed and shared in all the problems of the established malariologist. In addition he worked with the entomologist, parasitologist, and engineer, and their enlisted men in the laboratory and field. When possible, the staging malariologist was given a few weeks of work as head of an established group before being sent to an independent assignment.

The established entomologist outlined to the staging entomologist the methods of work, the system of records, and the peculiar problems of his territory. As soon as possible, the staging entomologist and his crew were assigned a portion of the base and made responsible for all phases of survey work therein. This plan enabled the entomologist to evaluate the abilities of his crew to do field work and to initiate additional training as needed. It was emphasized that this was only an elementary training and that further knowledge and proficiency developed with work. Field men were taught the application of survey to control and that they were the eyes of the larvicidal crews. The need for direct and immediate transfer of survey information to the control crews was stressed. It was emphasized that the field men were often first to recognize the need for drainage or other correction of man-made mosquito breeding sites. They were encouraged to develop the ability to recognize proper corrective measures applicable to such control problems and to make suitable recommendations. Selected individuals were instructed in insectary procedure and mosquito identification.

The engineers and the men of the control detachments went thru a similar apprenticeship. Oftentimes it was possible to place 6 or 8 men of a control unit with a Navy construction battalion or Army Engineer Company, where they

rotated through a program of work with dragline crew, transit crew, dynamite gangs, and heavy maintenance section.

The training of enlisted personnel as technicians qualified to read blood smears for malaria was one of the urgent problems in this early period. The apprenticeship training in this subject served not only the parasitology section of new survey detachments but also technicians from hospitals and other units who needed laboratory workers. The first school for technicians was started at Efate, using as instructors corpsmen who had been trained at the Navy Medical School. Fifty to one-hundred routine thick blood smears were examined each day by these corpsmen and were available for teaching purposes. Technicians of staging hospitals, and dispensaries were trained first, and later technicians of regimental aid stations and battalion sick bays. Similar schools were established on Santo, Guadalcanal, and other bases as soon as malaria control groups arrived. Students were trained either singly or in small groups. The course lasted from 2 weeks to a month, depending upon the background of the individual and the speed with which he became proficient in the work. Over 450 technicians were trained in the first 2 years of this work with an improvement in malaria diagnosis throughout the area to the point where over 95% of all cases were confirmed by the laboratory.

b. The School for Troop Unit Anti-Malaria Details was designed to teach the elements of larviciding and other control measures to the men who comprised these details in each company. This activity was initiated by a directive issued in September 1943[26] and revised October 1944 by ComSoPac 02158 which is quoted in part:—

"7. Each unit will arrange with the permanent Base Malaria Control Unit to hold a school for those officers and non-commissioned officers who are designated for malaria and mosquito control work. In planning these schools precedence will be given those units anticipating movement to forward areas. The following subjects will be taught:

a. Identification of anopheline larvae and adult mosquitoes.
b. Use of maps to mark breeding places.
c. Control of mosquito breeding by draining, filling, spraying with oil and use of drip oilers.
d. Assembly and repair of knapsack oil sprayers."

An effort was made not only to show how to control malaria, but also to explain the rational of this work, thus creating a nucleus of informed officers and men in each battalion and company. An average class consisted of 10 to 15 students. The officers and selected enlisted men from base and division malaria control groups comprised the faculty.

The presentation of subject matter was elementary. The unit medical officer was required to attend because he was expected to use this type of presentation in his talks with the men of his organization. Emphasis was placed on practical field work. Between 4000 and 5000 officers and men attended these schools during the first 2 years of their activity, Table X.

c. Educational program for all personnel. All of the above described pro-

[26] ComSoPac Serial 01619, dated 13 September 1943.

grams were concerned with personnel engaged in full or part time insect and rodent control work. The basic educational program, which is now to be described, aimed to impress every man with the importance of malaria and how he might protect himself from mosquito borne disease. Few troops had had any education in malaria before arrival in the area. The early need for this educational work was so apparent that programs were initiated almost simultaneously on several staging bases including Fiji, New Zealand and New Caledonia. The value of these early uncoordinated efforts was immediately evident. At the same time there was apparent need for a uniform area training and education program, for approved training manuals and for a publicity program employing

TABLE X

Attendance at malaria control schools

BASE	SCHOOL ATTENDANCE		LENGTH OF COURSE
	Officers	EM	
			days
New Zealand	100	75	5
Fiji	1	80	7–14
New Caledonia	300	700	1– 5
Efate	20	150	1– 2
Santo	106	574	2– 5
Guadalcanal*	225	1836	3
Russells	42	246	2
Munda-Segi	50	269	1
Bougainville	2	25	3
Green Island	0	25	3
Emiru Island	0	60	2½

* A school was held at each of the 4 sub-groups on Guadalcanl.

the radio and other educational aides. Excerpts from the training directive, ComSoPac Serial 02158, October 1944, are quoted as follows:

"Training Program in Malaria Control

"1. Unit commanders will allot in the training schedules sufficient time for the proper instruction of their troops in the principles of malaria prevention.

"2. Lectures will be given to small groups of men by their respective medical officers. These lectures will cover the following:

a. Military importance of Malaria.
b. Nature of Malaria. How Transmitted and Effects.
c. Individual Protective Measures, Conditions in Which Each is Applicable, Especially in Combat.
   Repellents
   Use of Ordinary Clothes for Protection.
   Spray-Killing of Adult Mosquitoes.
   Bed Nets
   Atabrine Suppressive Therapy.
   Avoidance of Unnecessary Exposure.
d. Control of Mosquito Breeding.
e. Man-made Malaria—How to Avoid it.

"3. All personnel will be given initial instruction in prevention of malaria by lectures and motion pictures as soon as practicable. Subsequently, a review of the subject will be carried out at least once a month.

"4. Additional instruction will be given to officers and non-commissioned officers, or petty officers, covering especially the selection of campsites, the hazard of natives as a source of malaria, and the enforcement of precautions under varying field conditions. Emphasis will be put on the responsibility of officers and non-commissioned officers for good "Malaria Discipline," and its importance to military success. Arrangements may be made to have members of Base Malaria Control Units assist in this program.

FIG. 4. POSTERS DESIGNED BY ARTIST AT AREA HEADQUARTERS WERE PRINTED AT RATE OF ONE PER ONE HUNDRED MEN

"5. To aid in this program permanently based Malaria Control Units (or Island Surgeons) will issue the following malaria training manuals:

All Medical Officers: MTM No. 1. Prevention of Malaria in Military and Naval Forces, SPA.

All Officers: MTM No. 2. Military Malaria Control, in the Field.

Enlisted Men: MTM No. 3. Malaria, Mosquitoes, and Men.

Movies, additional literature, posters, and other material will also be made available by Malaria Control Units.

"6. Every unit will periodically conduct field exercises in the practical application of antimalarial measures. On maneuvers, these measures will be standard procedures."

Every available educational aid was utilized (figs. 3 and 4). Arrangements were made for brief radio announcements on each base every evening which reminded listeners to roll down sleeves, to use repellent and to take other pre-

cautions. The radio stations were known as the Mosquito Network and on Guadalcanal a program of recorded music known as the Atabrine Cocktail Hour began each evening with a plug for malaria or dengue control.

G. CONTROL MEASURES

The primary preventive medicine problem in the South Pacific Area was the control of malaria; problems of secondary importance were the prevention of dengue fever, filariasis and tsutsugamushi disease. Enormous fly populations developed on all bases where combat was severe and where adequate sanitation was difficult or impossible to attain, yet fly control was not made the concern of the malaria control organization until late in the campaign. The lessons in fly control which were learned here were subsequently of great value in other campaigns where fly control was a major effort.

Before considering the measures employed against larval and adult mosquitoes a brief account will be given of the problems of segregation of natives and of methods to enforce the use of individual protective measures against mosquitoes.

1. Enforcement of individual protective measures

The education of all personnel in the value of individual protective measures has been discussed above and was followed by the publication on each island base of directives and report forms pertaining to malaria discipline, Exhibits I and II.

Each unit commander or his representative was responsible for routine inspections to assure malaria discipline in his unit. Base and division malaria control officers made spot inspections to determine compliance with directives.

EXHIBIT I

HEADQUARTERS FORWARD AREA
APO ✱...
24 November 1943

Memorandum Number 14

INDIVIDUAL MEASURES TO PREVENT MALARIA

1. This directive supplements AG 300.6 (Y-P), this Headquarters, dated 27 October 1943.

2. Between the hours of 1800 and 0630, personnel not under a mosquito bar or in screened quarters will wear long trousers and shirts with sleeves rolled down.

3. Use of repellents: Ten to fifteen drops of repellent should be rubbed on hands, wrists, face, and neck at dusk, and will be repeated every three hours when exposed at night.

4. Use of insecticide, aerosol, 1-lb dispensers: All tents should be sprayed before bedtime. Ten seconds spraying is adequate for a pyramidal tent; more is wasteful.

5. Night raids and alerts: Foxholes will be sprayed immediately after entering. Repellent will be taken to foxhole and used as directed in par. 3.

6. All personnel not housed in adequately screened quarters will sleep under mosquito bars properly attached.

7. Swimming, and taking showers in unscreened bath houses, and other unnecessary exposure between the hours 1800 and 0630 are absolutely prohibited.

8. Good Malaria Discipline means that the individual protective measures listed above are continually and consciously carried out by each member of an organization. Such discipline is a command function. Unit commanders will hold their unit malaria control officers responsible for making necessary inspections and reports. Inspectors from Base Malaria Control Units will make spot checks, and report directly to this Headquarters.

By command of MAJOR GENERAL .....

EXHIBIT II

HEADQUARTERS X ISLAND COMMAND
APO #.....

.....
(Date)

Subject: Violation of Malaria Discipline
To: Commanding Officer, ...
Ref.: A. Memorandum #14, Hqs, For'd Area, APO ....., 24 November 1943

1. The violation of malaria discipline by a member of your command or occurring in your camp area, is reported:
   a. ☐ Improper uses of clothing, (no shirt, short trousers, sleeves rolled up, shirt unbuttoned).
   b. ☐ No mosquito bar, or improper use of same.
   c. ☐ Swimming, or taking showers in unscreened quarters after dark.
   d. ☐ Atabrine administration:
      (1) Inadequate supervision.
      (2) Failure to maintain adequate roster.
2. Time and Place of Violation: .....
3. Names of Individual Violators | Organization | Violation (a, b, c, d)
   ..... | ..... | .....
   ..... | ..... | .....
   ..... | ..... | .....
   ..... | ..... | .....
4. Remarks: .....
   .....
   .....
5. Officer with whom inspection was made: .....
6. Malaria Control Inspector: .....
7. Report of action taken (is) (is not) desired.

By command of MAJOR GENERAL .....

The usual procedure of the inspecting officer was to walk through the camp after dark, take the names of any men improperly dressed, inspect a few bed-nets, and inquire about supplies of repellent and the atabrine roster.

The malariologist and his assistants were responsible also for inspection of planes and ships to assure compliance with directives designed to prevent dissemination of mosquitoes from one base to another. Weekly spot inspections of outgoing planes were made at all airfields and seaplane bases. Violations were reported to the Island Commander. It should be remarked that inspections made in 1942 and 1943 indicated frequent failure to disinfect both ships and planes. Yet, no anopheline mosquitoes had been found in New Caledonia, Fiji, Samoa, New Zealand or other non-malarious bases as late as July 1945. The malariologist at non-malarious bases was responsible for anopheline surveys around airports and harbors and for investigating cases of malaria claimed to have been contracted on non-malarious bases. Numerous rumors of such cases were all groundless as of July 1945.

2. Segregation of Natives

Surveys presented in Paper IV show that the natives were a serious hazard as a seed bed of both malaria and filariasis. The malaria epidemic index (splenic

index combined with parasitic index) was more than 75 per cent. The microfilaria parasitic index was more than 20 per cent. The size of the problem is shown in Table XI.

Table XI shows that the indigenous natives seldom were a serious problem on bases occupied by assault, most villages being evacuated voluntarily during the combat period. Movement of villages which were included within the perimeter during peaceful occupation or expansion of a base was more difficult. An official recommendation for removal was initiated by the malariologist and was sent to the Island Commander who made representations to the Colonial authorities. This process was rarely effective in the New Hebrides where the interests of

TABLE XI

*Native seed bed of malaria and filariasis—approximate numbers within one mile of troops**

BASE	MELANESIANS		TONKINESE	SCHOOLS	TOTAL
	Indigenous	Imported Labor			
Efate	700	300	200	180	1380†
Espiritu Santo	0	300	700	30	1030
Guadalcanal	50	2200	0	0	2250
Tulagi-Florida	‡	246	0	0	246
Russell Islands	400	675	0	0	1075
Segi	0	0	0	0	0
Munda & Ondonga Area	0	0	0	0	0
Vella Lavella	0	0	0	0	0
Treasury	180	0	0	0	180
Bougainville	0	1600	0	0	1600
Green Island	120	0	0	0	120
Emiru	225	40	0	0	265
Total	1675	5361	900	210	8146

* As of May 1944.

† About 1000 heavily-seeded white Europeans were also within one mile of troops.

‡ 4 villages, population not known, were within one mile of troops.

plantation owners were involved, yet the same method was usually successful in the Solomons where plantations had been abandoned as the Japanese invaded. The natives listed as imported labor were about 70 per cent of the total number of natives within perimeter and were usually brought in to the occupied area from an adjacent island by the colonial labor corps. They were quartered in labor camps. These laborers were urgently needed in the conduct of military operations and the command decision was to use them in spite of their hazard as a seed bed. The chief exception to this policy was on Espiritu Santo where the malariologist persuaded the Island Command not to use native labor. The absence of an epidemic of malaria on this base at the time of the great outbreaks on Efate and on Guadalcanal resulted, at least in part, from the decrease in the seed bed thus accomplished.

The legal basis for dealing with the native problem was found in ComSoPac Serial 5936, dated 29 October 1943, which is quoted in part:

"Island commanders will maintain close watch on potential native sources of malaria and filaria infections. They will make appropriate recommendations to Commander, South Pacific Area, in each case where natives are considered a potential menace.

"Medical Officers of the United States forces are hereby authorized to undertake the treatment of indigenous natives to reduce the health hazard to our forces. The expenditure of medical supplies for this purpose is authorized.

"The above command also applies to natives, imported or employed by civil firms so located as to be a health hazard to our forces."

In the early days of small perimeters and acute shortage of transportation, labor corps camps were located near their place of work, usually a ration or ammunition dump. These locations were often immediately adjacent to troop bivouac sites.

Removal of native labor camps to at least a mile from troop bivouac sites was the goal on all islands; until this could be accomplished reliance was put upon a larvicidal oiling program and drug therapy. Spraying of native huts with freon aerosol pyrethrum "bombs" was initiated in October 1943 when these became available in quantity.

Labor corps officials who assisted in the administration of anti-malarial drugs to natives warned that forcible measures would probably be required to make natives take such medication. However, the writers have personally administered atabrine to thousands of natives without a single refusal by the simple expedient of first publicly swallowing a tablet themselves. The suppressive dose was atabrine 0.1 gm daily. Occasionally this was supplemented by mass therapy and then the dose was atabrine 0.3 gm daily for 7 days. This was followed in the early days by plasmochin 0.020 gm daily for 5 days. Data in Table XII shows that while such therapy reduced the incidence of parasitemia, that parasites were still found in about 2 per cent of natives. The incidence of sexual forms was too low to be significant. Subsequent information on the "curative" action of atabrine on falciparum infections suggests that this therapy was more valuable than was appreciated at the time.

The relocation of native labor corps camps created a continual conflict of interests. The malariologist wanted to remove all such camps a mile or more from troops. The Service Command wanted natives to be located near the site of their work so as to conserve transportation. The colonial labor officers objected to being moved from desirable sites in a populated area to remote and new locations. Despite these difficulties, most of the labor corps natives were relocated by the middle of 1944. This was often an expensive and time consuming procedure, as was witnessed by the removal of a large labor camp on Guadalcanal which required the building of more than a mile of all weather road with drainage system.

The native Melanesians were enthusiastic traders and found our troops to be eager and gullible customers for all kinds of native handiwork. It was suspected that not a few "war clubs" were roughed out on power lathes, polished and

properly marked by native entrepreneurs and sold to the mutual benefit of all producers. However, the shoe was sometimes on the other foot and an occasional pleased and credulous native was seen walking home with G. I. equipment which included an electric light bulb and socket with a foot of attached wire. One suspected that international relations were not improved when he hung up his bulb and turned the button. This urge to trade and to sightsee led to continual violation of regulations prohibiting natives from camp areas after dark and placing native villages "out of bounds" for troops.

TABLE XII

*Effect of therapy on malaria incidence in native laborers**

ISLAND OF ORIGIN	BEFORE TREATMENT		TREATMENT	AFTER TREATMENT†	
	Examined	Positive		Examined	Positive
	No.	%		*No.*	%
Guadalcanal	106	10	Mass atabrine-plasmochin	204	1
Malaita	241	12	Suppressive atabrine	1022	2
Malaita			Mass atabrine-plasmochin after suppressive atabrine	90	2
San Cristobal	219	7	Suppressive atabrine	400	2

* These studies were carried out on adult males quartered where malaria transmission was at a minimum.

† Examinations made 1 to 10 days after treatment.

Selection of camp sites was closely allied with the segregation of natives and aimed also to locate military installations away from mosquito breeding places. The following paragraphs are from pertinent directives:[27]

"It is directed that officers in charge of malaria control units be consulted in connection with selection of sites of camps and airfields, and that their recommendations in such matters be given due consideration.

"Information concerning any contemplated troop movement of any force coming to or leaving a malarious base will be made known by the island or force commander to the senior malaria control officer at each base concerned as early as such information is received."

The duties of the malariologist in the selection of campsites included liaison with G-3 concerning contemplated troop movements, survey of proposed campsites with the entomologist and engineer, preparation of a list of suitable campsites of various sizes, preparation of a list of unsuitable regions difficult or impossible to control, with a recommendation that they be declared out of bounds for bivouac purposes and initiation of control work in and around new campsites at least a month prior to occupancy.

The prerequisites of a campsite changed with the tactical situation. Protective cover in the form of palm grove or jungle was a primary consideration under conditions of combat or bombing regardless of increased exposure to malaria.

[27] ComSoPac Serial 0094b, 13 November and Hq., USAFISPA, 29 November 1942, and AG 720, Hq., USAFISPA, 24 May 1943.

Open sites, even though less of a malaria hazard were not acceptable until the tactical situation no longer required protective cover. If the malariologist acquiesced in an initial poor location, he was expected to recommend a more favorable location as the tactical situation improved. If a mile between troops and natives was not immediately feasible, a lesser distance was accepted temporarily, and increased as soon as possible. Any distance over a half-mile was of distinct value in decreasing transmission of malaria and filariasis; and even shorter distances decreased the hazard of dengue. The policy of avoiding heavy anopheline breeding sites was recommended whenever compatible with military plans. However, because of restricted beachhead perimeters and the military importance of rivers it was rarely possible to locate troops a mile or more from swamps, river deltas, and other anopheline breeding areas. Rather, it was necessary to control mosquito breeding in such regions.

It was also the duty of the malariologist to suggest relatively malaria-free regions for night maneuvers and amphibious landing drills. He surveyed the regions which were available for such tactical operations with the entomologist and informed G-3 of those which were suitable. He advised that highly malarious territory be placed out of bounds for night exercises until it could be brought under control. Even when night exercises were held in authorized sectors, all anti-mosquito precautions were regularly enforced, both for protection and as a training measure.

3. Larvicidal Work—Ground Application

It is worthy of note that larvicidal operations were well developed on all bases before DDT became available. Larviciding was usually the first type of insect control to be done on a new base. Detailed maps were essential for this work and if available, aerial mosaics were studied before arriving. These maps were corrected and new information added each day by both survey and control personnel. The initial larviciding rapidly progressed to a routine oiling program which usually followed a weekly schedule. Insect control work in territory occupied by troop units was assigned to the anti-malaria details of those units. The remaining territory was controlled by labor directly available to the malaria control engineer, Table IX. The engineer divided the labor available for larviciding into crews of 5 to 15 men and assigned to each crew a section of territory which it was to larvicide completely in 4 to 5 days under optimum conditions. This allowed a safety factor for breakdown of equipment, bad weather and other problems, while still permitting a weekly schedule. Men were given 1 day each week for recreation; although in urgent situations, especially in the wet season, a 7 day work week was customary.

"Shock" oiling crews were organized on some large bases to control urgent breeding situations without interfering with the routine of regular crews. Oil depots were established at locations selected by the engineer and his foreman to facilitate oiling and to decrease transportation.

The clearing of stream banks (figs. 5 and 6) and of stream beds was an essential preliminary to adequate oil coverage. This work started with the initial larvi-

FIG. 5. STREAM CLOGGED BY DEBRIS AND COVERED WITH ALGAE MAT BEFORE CLEARING

FIG. 6. SAME SITE AS IN FIGURE 5, AFTER CLEARING. SHADE FOLIAGE HAS BEEN PRESERVED

ciding and was carried on simultaneously. Since sunlight encouraged the breeding of *A. farauti*, it was important to preserve as much shade as possible. Trees were not removed and only a 3 or 4 foot margin was cleared along stream banks to make a path for oiling crews. Natives, working with machetes, were superior to any other labor for this work. Bulldozers were less desirable since they needed a large area in which to operate and cleared a strip 20 to 50 feet wide. Revegetation of cleared areas made reclearing necessary at intervals of 3 to 5 months. This maintenance work was usually done in a fraction of the time required for the original clearing.

Light diesel oil, (Quartermaster item, 7–0–200, oil fuel, grade FS2) was the chief larvicide used in this theater until the introduction of DDT. Table XIII

TABLE XIII

Monthly consumption of diesel oil for larviciding—comparison of dry and wet season reports

BASE	AREA TO BE CONTROLLED	DRY SEASON*	WET SEASON†
	sq. miles	*55 gallon drums*	*55 gallon drums*
Efate	39	180	250
Espiritu Santo	40	255	360
Guadalcanal	110	650	1800
Tulagi-Florida	9	70	120
Russells	15	90	270
New Georgia	20	50	100
Vella Lavella	20	30	100
Bougainville	30		85
Green Island	15		90
Emiru	30		100
Totals	328	1325	3275

* From reports for October and November 1943.

† From reports for January and February 1944, except for Green and Emiru.

Note: When the amount of oil used by troop units was not reported the island figure was increased by approximately 20 per cent.

shows the comparison between amounts used in dry and wet seasons. No DDT was used in the periods reported in Table XIII.

Paris green eventually was completely replaced by DDT. Paris green was used chiefly as a temporary measure along grassy stream margins and the edges of swamps until proper clearing could be instituted in such places. Relatively small amounts were used. Lack of a suitable diluent and of good dusters were the chief obstacles to the wider utilization of paris green. Condemned flour was the most commonly used diluent and became lumpy and unsatisfactory because of the high humidity and contamination by mold and bacteria. No lime was available.

Kerosene and unleaded gasoline were used to treat native wells and water tanks which could not be closed or screened. When applied in the evening the kerosene evaporated before morning and did not affect the potability of the

water. The amount applied was 4 ounces of kerosene per 100 square feet of water surface.

DDT began to arrive in quantity about the middle of 1944. DDT in oil was used as a 5, 2.5 and 1 per cent solution. Since each type of spray equipment delivered a different minimum output of DDT-oil solution the concentration was varied accordingly. The minimum concentrations of DDT in oil shown in Table XIV gave nearly 100 per cent kill when adequately applied.

The use of DDT resulted in great economy of labor and of diesel oil. A medical sanitary company on Guadalcanal equipped with flit guns, reported that their monthly output of DDT-oil solution to larvicide a stipulated area was 150 gallons. This amount represented 10 per cent of the 1500 gallons of plain diesel oil formerly used to cover the same area with knapsack sprayers. Others advantages of DDT-oil over plain diesel oil were the decreased weight carried by

TABLE XIV

Relationship of DDT concentration to minimum output of equipment

Guadalcanal, June–October 1944

EQUIPMENT	MINIMUM OUTPUT	RECOMMENDED MINIMUM CONCENTRATION	
		Per cent	Lbs DDT per acre
	gal./acre		
Knapsack and C. W. Decontamination Sprayer	5–7	1	0.48*
"Flit Gun" type sprayer	1.2–2	2.5	0.3*
Airplane	0.5	5	0.2

* Pounds of DDT/acre for "Flit Gun" sprayers calculated on output of 1.5 gal/acre; for knapsack and C. W. decontamination sprayers on output of 6 gal/acre.

each field man and the less frequent filling of sprayers and replenishing of oil depots.

The introduction of DDT did not alter the weekly larvicidal schedule, although heavier applications of DDT in a few static pools did give a residual larvicidal effect for longer periods. The chief breeding areas, however, were of a nature which did not lend themselves to larviciding for residual effect. This fact and the heavy rainfall during the wet season made it necessary to maintain the weekly larvicidal schedule for the major portion of control work.

DDT dusting preparations were used much less than DDT-oil solutions. Ten per cent DDT dust gave excellent larvicidal action when dusted on small water surfaces such as road ruts or rain barrels and survey men usually carried a 2 ounce can to treat small breeding places when found. Dispersion of DDT dust over large water surfaces was frequently handicapped by unsatisfactory dusting equipment. In addition to the same difficulties with diluents for DDT, as is noted above for paris green, it was reported that DDT and lime were chemically incompatible. The 10 per cent DDT dusting powder was ordinarily used without dilution.

The equipment for application of DDT-oil solutions will be discussed briefly. Knapsack sprayers were available in 3 and 5 gallon sizes. The Chemical Warfare Item, Apparatus, decontamination, 3-gal cap., M-1, pressure type sprayer when modified with a suitable nozzle and oil-resistant hose was the lightest, most durable and generally satisfactory knapsack sprayer. It was reasonable to standardize on this one sprayer for both insect control and chemical warfare uses. The natural rubber hose on both of these sprayers deteriorated rapidly after contact with oil and small particles of rubber broke off and clogged the screen, whirl plates and spray disc. Neoprene or other oil resistant hose solved this difficulty.

The "Flit Gun" type sprayer[28] which was equipped with an atomizing nozzle was one of the most useful instruments available for ground application of DDT-oil solutions. This sprayer delivered a fine spray which was effectively applied in still air or when aided by a wind drift. Operators were trained to take advantage of wind direction to obtain maximum coverage with minimum amount of larvicide and effort. A visible film of oil was not always detectable on the water. The best criterion of coverage was a larval survey before spraying and 24 hours after spraying. Surveys made less than 24 hours after spraying often gave erroneous results because of the delayed killing action of DDT.

Aerosol generators[29] were tried extensively on Guadalcanal and proved to be of value both for larviciding and for killing of adult mosquitoes but their use was limited by the need for particular meteorological conditions and by mechanical problems of operation.[30] This generator was also useful for sand-fly control along an occupied beach.

Mixing of DDT with oil became a problem as its use increased. Simple hand mixing gave way to various types of mechanical agitation; one of the best being improvised from an orchard sprayer. Larger scale mixing plants made use of compressed air which was released at the bottom of a steel cube or other suitable container and so agitated the oil-DDT mixture.

4. Larvicidal Work—Airplane Application

Airplanes were first used to disperse DDT solutions in the Spring of 1944.[31] The work was carefully controlled by surveys of larval and adult mosquito populations and observations on droplet size and dispersion.[32]

Both small and large airplanes[33] were used in this program and each was fitted with a suitable spray apparatus. Small planes were both valuable and eco-

[28] Listed as QM item 41-S-40105. Sprayer, liquid, insect, continuous spray, 2 qt. size.

[29] Hochberg La Mer Insecticidal Generator.

[30] Newsletter #20 and 22, Hq., Malaria and Epidemic Control, South Pacific Area, February 1945. Abstracts from report of Bohart et al.

[31] Mr. C. N. Husman and officers from Naval Medical Research Unit No. 2 aided in the initiation of this work.

[32] Fallander, S. R.: Analysis of Aircraft Spraying and Equipment in Malaria Control. A.G. 452 (Y-P) Headquarters Guadalcanal Island Command, 23 March 1945.

[33] Maple, John D., The Spraying of DDT from Aircraft, Newsletter 17, Hq., Malaria & Epidemic Control, SoPac Area, November 1944.

nomical as an adjunct to ground coverage. The maneuverability of small planes was an asset in covering small areas which were difficult of access to ground crews. Cub type planes were used to larvicide a field of uncharted land mines, a series of dense coastal swamps and jungle tracts where mosquito breeding was increased by logging operations. Larger, faster planes were valuable to obtain partial and temporary mosquito control over large areas of newly occupied terrain during the period when ground crews were establishing control.

a. Small planes.—The equipment for use in small planes was known as the Husman-Longcoy spray apparatus and was designed at the Bureau of Entomology, U.S.D.A., Orlando, Florida, for installation in the 65 h.p. Piper Cub airplane.[34] An improved light weight spray apparatus was later designed and used on Guadalcanal and Espiritu Santo (fig. 7). The capacity of the spray tank was 25 gallons which was adequate to spray 50 acres. The area which a cub plane could cover was adversely affected by rain, which decreased visibility, and by winds in excess of 15 miles per hour, both of which made low flying dangerous. It was estimated that average conditions would allow a single cub plane to cover up to 300 acres per day for a 4 day week; under ideal conditions this might be increased to 400 acres per day. The remaining 3 days allowed for inclement weather, plane servicing, and for miscellaneous delaying factors. Flight lines were 40 feet apart regardless of wind or altitude, but it was desirable to fly cross-wind to take advantage of drift. Flag men were used to indicate these flight lines only until the pilot was able to maintain parallel flights at 40 foot intervals. The flight altitude averaged 25 to 35 feet over open grasslands and 125 feet to 150 feet above the ground over palm groves and jungle.

A ground crew of 2 to 3 men with a $\frac{3}{4}$ ton truck and a tank trailer was equipped to service as required each 1 or 2 cub planes. This truck unit carried a motor driven fuel pump, gasoline, DDT-oil solution and other necessary equipment and made it possible to use small temporary landing fields near the site of spray operations. The number of spray flights which a plane could make each day depended largely upon the efficiency of the ground crew in servicing the plane.

b. Large Airplanes.—TBF and TBM planes were the larger planes which were adapted for airplane application of DDT solutions. The 2nd Marine Airwing used a TBF plane for spraying during early operations on Peleliu Island. An improved apparatus was subsequently designed and used on Guadalcanal. All equipment was standard for this airplane or available on the island. DDT solution was carried in the standard 265 gallon belly tank. A speed of 115 knots with 15 degree flaps was selected as giving the best distribution while maintaining maneuverability of the plane. A swath width of 150 feet gave a uniform deposit of 2 qts. per acre. At this rate of 2 qts. per acre the 265 gallons in the belly tank covered approximately 500 acres. The minimum time required to spray this amount was about 13 minutes. Field tests with both the L4B and the TBM repeatedly showed that the larvicidal action of 2 qts. per acre of 5 per cent DDT solution in oil was equivalent in larvicidal effect to careful ground coverage.

[34] L4B and AE-1 were the army and navy designations for the two types of planes which were used.

FIG. 7. AE-1 PLANE SPRAYING DDT SOLUTION. NOTE TWELVE FOOT SPRAY BAR UNDER FUSELAGE

5. Measures Directed against Adult Mosquitoes

Spray killing of mosquitoes was almost entirely limited to the use of pyrethrum aerosols, and to insecticidal preparations of DDT. Pyrethrum insecticide, aerosol, 1-lb and 5-lb dispensers were used to kill mosquitoes in bed nets, screened buildings and covered foxholes. The value in open foxholes and unscreened tents was transitory. Aerosols were little used in combat areas. They were used to spray native huts located near troops. Spraying was done each morning, and a native dresser was trained in the work. This method of mosquito control was effective because of the habit of *Anopheles farauti* to rest for several hours in the hut or tent where the blood meal had been recently obtained. The plan of weekly spraying, as applied to *A. culicifacies*, *Giles* (12), was not thought adequate because there was no evidence of prolonged resting of *A. farauti* in hutments.

DDT preparations designed for residual effect were applied to the inside woodwork and screening of tents and buildings and to the palm leaves and bamboo stems of the interiors of native huts. The most satisfactory application was made by means of a power driven paint sprayer. One pint to one quart was applied to each 250 square feet of surface. A satisfactory rule of thumb was to spray the surface to wetness: i.e., a pattern of closely packed droplets, but not to the extent that the liquid would run from the sprayed surface. Best results were obtained by running the engine at slow speeds and regulating the pressure to less than 50 pounds per square inch. The tendency of untrained personnel was to use higher spray pressures of 150 to 200 pounds per square inch which atomized the spray and gave less satisfactory coverage.

The effect of residual spraying with DDT on living quarters was remarkable. Mosquitoes and flies observed to light on a treated surface developed toxic symptoms within 1 to 2 hours and died within 6 to 24 hours. Ants previously very annoying in tents and huts disappeared. A single application was effective for about 3 months depending on exposure to weather.

Bed nets impregnated with 5 per cent DDT in kerosene. Tests on impregnation of bed nets with DDT were begun in the latter part of 1944, and the methods then developed were used to treat the bed nets and jungle hammocks of 2 divisions. A 5 per cent solution of DDT in kerosene was applied by a power driven paint sprayer or by Chemical Warfare decontamination sprayers, provided with whirl plates and spray disc nozzle to deliver a large size droplet. The bed nets were arranged in piles. The top net was sprayed on one side, reversed to start a new pile and then sprayed on the other side. Six men were able to spray about 60 to 100 nets per hour with hand sprayers and twice this number with a power driven sprayer. This included the preparation of nets, spraying, and the hanging in the sun to dry. One gallon of solution treated 6 to 8 nets.

Treated nets were stored for over a month and then hung over a cot in the usual manner and observed to determine the lethal effect on *A. farauti* which were liberated within the net. Ninety-three of 94 mosquitoes were dead within one hour while no control mosquitoes died in an untreated net. In another test 224 mosquitoes were liberated within the treated net for 10 minutes or less, and were

then recaptured and placed in untreated cages. All were dead within 24 hours of this brief exposure, while no controls died. In the second test an observer remained in the treated net with the mosquitoes and noticed that they attempted to bite during the first 2 minutes, but not after 5 minutes (13).

All the bed nets of one division and the jungle hammocks of another division were treated with DDT solutions during the last weeks prior to departure for uncontrolled, malarious areas. The effect of carrying bed nets in barracks bags where they were subject to frequent handling was not known.

Bed nets proved to be the most valuable single measure against mosquito bites. There were instances on Guadalcanal and other bases during the height of the malaria epidemics where less than a week of bivouacing without bed nets resulted in a high infection rate among unprotected troops. Orders were issued making it the responsibility of each officer and man that bed nets should be available on the first night ashore except among troops actually in combat. Compliance was generally excellent after the early costly experiences. The educational program continually emphasized the importance and the proper use of bed nets. The early shortages of bed nets and particularly of replacements was part of the total supply problem. Replacements of bed nets was adequate on rear bases from the fall of 1943 and on all bases by the end of that year.

Jungle hammocks became available and were issued to many troops including whole divisions beginning late in 1943. These hammocks when properly suspended were excellent and facilitated net protection in forward areas and outposts. However, the issue of jungle hammocks to entire divisions was of doubtful value because of two reasons. First, because of their bulk they were one of the first items to be discarded during combat operations. Secondly, it was rarely possible for any significant number of men in a division to find trees or other supports adequate for the suspension of these hammocks.

Head nets were issued to all troops and were not used. The use of head nets for protection during sleep was not practicable because the movements of the sleeping individual soon disarranged the head net or brought it against his face and so allowed mosquitoes to bite through the meshes. The routine issue of head nets was not warranted under conditions prevailing in the South Pacific.

Repellents. Only 612 and dimethylphthalate, of the available repellents,[35] were effective against the *Anopheles farauti*. 612, when adequately applied repelled anophelines for about 2 hours. Dimethylphthalate was effective for much shorter periods. Profuse sweating decreased this repellent effect. Combat troops frequently claimed that Japanese could smell repellent for many yards if the wind was in the right direction. Service troops disliked the messiness of a repellent and used it only when mosquito bites were annoying or when malaria discipline was strictly enforced. Repellents were potentially a valuable individual protective measure but were relatively little used. Supplies were adequate from the middle of 1943 and a surplus supply in the area of over 12 million bottles by the end of 1944 was evidence of lack of use.

[35] The new standard Q.M. repellent "6–2–2" was not available until 1945 and was not tested. 6 parts dimethylphthalate, 2 parts Rutgers 612, 2 parts Indalone.

Screen, cloth bobbinette and wire. Screen was slow to arrive. By early 1944 it was available in adequate amounts in all except forward and combat areas. Table XV shows the relationship between length of occupation of each base and the per cent of screened quarters as of June 1944. Cloth bobbinette was preferred to wire for field use and for use on installations near enough to the shore to be subject to wind-blown salt spray. Under these latter conditions cloth bobbinette outlasted wire. It was lighter to ship, required less space per cubic yard, and used no critical materials. Wire or plastic screen was preferable away from the shore in semi-permanent buildings such as hospital wards and mess halls. When screen was limited in amount, the following priorities were established: hospitals; kitchens and mess halls, showers, particularly for organi-

TABLE XV

Estimated per cent of quarters screened as of 1 June 1944

BASE	DATE OF OCCUPATION	HOSPITALS ARMY-NAVY	KITCHENS & MESS HALLS ARMY-NAVY	SHOWERS		TENTS	
				Army	Navy	Army	Navy
Efate	Mar. '42	100–100	100– 95	90	90	100	100
Santo	May '42	100–100	100–100	90	95	90	90
Guadalcanal	Aug. '42	100–100	90– 90	65	70	90	90
Tulagi-Florida	Aug. '42	100–100	100–100	100	100	100	90
Russells	Mar. '43	100–100	40– 40	5	5	10	10
Munda	July '43	100–100	100–100	10	20	40	30
Bougainville	Nov. '43	100–100	100–100	50	15	5	5
Green Island	Feb. '44	100–100	100–100	40	25	15	10
Emiru	Mar. '44	100–100	100– 95	75	25	20	2

Note: Navy data includes that of Marines.

zations with men on night details; latrines; offices, tents, and all other living quarters. The recommended initial allowance was 16 linear feet of screen bar per man and 4 feet per man per month as replacement.

6. Semi-Permanent and Permanent Control Work

Filling. Most filling operations were concerned with the elimination of man-made breeding places such as foxholes, borrow pits, bomb craters, and road ruts. Foxholes along the shore and especially in coconut groves were filled and levelled most economically by bulldozers. Foxholes in the jungle usually were hidden along lines roughly parallel to streams. Finding and filling these was a project best done by native labor.

Drainage: Hand ditching. Medical sanitary companies were organized with ditching platoons and on some bases dug many miles of excellent ditches which greatly reduced the work of larviciding. Small feeding ditches in a bivouac site were made with hand labor by the troops concerned. Large main drainage ditches were not usually dug by troop labor. The full potentialities of hand ditching were realized only rarely as in the 37th Division Area on Bougainville. Survey and oiling crews were urged to be alert to the possibility of hand drainage

since a very small ditch often released a surprising amount of water and saved much larvicidal work.

Dragline ditching. A $\frac{3}{8}$ to $\frac{3}{4}$ yard dragline was the most valuable piece of ditching equipment for malaria control. Dragline ditches were particularly economical for draining swamps, connecting cut-off oxbows into streams, putting in deep roadside ditches and channeling streams. A native crew usually cleared

FIG. 8. DITCHING WITH BANGALORE TORPEDOES. NOTE HOW MAN ON BANK SINKS INTO SOFT MUCKY SOIL

a path through jungle or swamp for the dragline and natives or sanitary company labor followed to smooth and finish the sides. Ditch sides were made with a gradual slope to prevent collapse. Mats on which to walk the dragline were necessary in very wet ground and especially during the rainy season. With this aid and proper job selection, it was possible to work heavy equipment in wet weather on all bases in the South Pacific.

Ditch-digging machines. These machines had only limited value. They worked poorly in coral. The ditch produced by these machines was too narrow

and the vertical bank tended to collapse. When used they were followed by a pick and shovel gang to cut back the side walls to nearly 45 degrees.

Ditching with dynamite and bangalore torpedoes. Dynamite and bangalore torpedoes were used to advantage in blasting ditches and in clearing of obstructions and emergent vegetation in areas which were too wet for economical machine ditching. Straight fifty per cent nitroglycerin dynamite was used when available to blast inexpensive and effective ditches through swamps, marshes and ponds. Residual drainage of lake bottoms which had been partially drained by other methods was easily accomplished by blasting with dynamite. Dynamite was also used for blasting stumps and submerged obstructions during clearing operations.

Bangalore torpedoes (fig. 8) were used to best advantage in clearing right-of-ways through swamps and obstructed streams to permit passage of malaria

TABLE XVI

Ditching by malaria control units

BASE	AREA TO BE CONTROLLED	MILES OF DITCHING		
		Dragline*	Bangalore or Dynamite	Hand
	sq. miles			
Efate	39	7	1	25
Espiritu Santo	40	13	6	2
Guadalcanal	110	87	7	75
Tulagi-Florida	9	5	2	27
Russells	15	29	2	3
Munda	20	5	1	3
Treasury	7	2	0	6
Bougainville	50	5	5	12
Emiru	30	4	2	0

* Included a small amount of work by ditch digging machines.

control boats and in channeling lagoons and lakes which were covered with floating mats of vegetation. Upon fragmentation, the hundreds of small sharp pieces of steel would act as knives in cutting this light material. The torpedoes also worked well in blasting ditches in wet muck.

The amount of ditching by malaria control personnel up to July 1944 is shown in Table XVI.

Vertical drainage. Vertical drainage required an underlying coral or sand base. This method was used on the Russell Islands where there were numerous large sink holes. A pit was dug, 4′ x 4′ x 6′ deep, near one side of the sink hole to which it was connected by a narrow channel. A screen in the channel kept out debris. On Munda, Ondonga, and Bougainville large bomb craters gave excellent vertical drainage in a few instances. When such drainage was well established, hand ditches were dug radially and a large area was thus drained. Vertical drainage holes were in constant danger of being filled with silt or debris.

A charge of dynamite exploded in the bottom of such a silted-up drainage hole often corrected the condition.

A unique type of vertical drainage was used on Green Island to aid in the elimination of extensive road ruts. These ruts averaged 6 inches in depth and contained water which had to be eliminated before the ruts could be filled. Pools of water in the road were drained by forcefully driving an iron rod down through the water and thin layer of soil into the underlying porous coral. A single strong blow often sank the rod to a depth of 6 feet or more, and as much as 20 gallons of water were drained rapidly by multiple holes. The space thus freed of water was filled in by a crew of hand laborers and the road closed to traffic. About 75 miles of ruts were treated in this manner.

Road drainage. A faulty road drainage system or lack of any road drainage was one of the chief causes of man-made malaria in the early months. Not only were borrow pits dug without provision for drainage but roads were built across natural drainage courses without any provision to care for the water thus impounded. In the wet season thousands of acres of breeding area were created as well as more acres of road ruts. The solution to this problem was adequate roadside ditches with culverts placed to grade. Satisfactory drainage required that a ditch be deep and large enough not only to drain water from roads but also to drain adjacent fields and camps. On bases occupied in the latter part of the campaign this problem was largely avoided by proper construction of roads. Fill for these roads was obtained by digging wide gutters on both sides, only down to drainage grade rather than from deep borrow pits. Roadside ditches were put in simultaneously with the roads and culverts placed to grade. On Emiru, an island policy was established that all roadsides should be drained either to the sea or to a natural drainage course and that this was the responsibility of the road construction group.

Road ruts in little travelled secondary roads, in abandoned jungle roads, and in dumps of all kinds were a great source of anopheline breeding. A heavy disc harrow pulled by a tractor (fig. 9) was the most efficient means of filling and smoothing these ruts, except in very wet ground. The discing leveled the ruts, pulverized the soil and encouraged growth of grass and other vegetation. Roads which no longer had military value were blocked with barbed wire and by the use of suitable signs. The use of these signs was approved by the Commanding General and they were erected in cooperation with the Provost Marshal.

Concrete Inverts. Concrete inverts and other types of permanent lining for ditches were not used on any base in the South Pacific because no concrete was available. Many Islands were occupied, developed and abandoned in such a brief period that such permanent work would have been inadvisable even if materials had been at hand.

Flumes. Lagoons and swamps just back of the beach offered the worst breeding problems on Guadalcanal. Similar problems existed on Bougainville, Green Island, Emiru, and other bases. On Guadalcanal there were over 60 such lagoons in the occupied territory. These were formed by wave action which built up a sandbar across the mouth of a stream in such a way as to form a dam.

The water within the lagoons was increased by rain and stream water to raise the level as much as 3 or 4 feet above sea level, thus providing an ideal breeding place for anophelines. Cutting ditches through the sandbar offered only a temporary solution. The first flumes were located at the narrowest point in the sandbar between the lagoon and the sea. This was the weakest point of the sandbar and at flood time the water often broke through to the sea and washed out the flume. Subsequently, flumes were located at a stronger place in the beach, well to one side of the flood point. The lagoon end of the flume

FIG. 9. DISC HARROWS WERE USED TO ELIMINATE RUTS IN DUMPS, IN ABANDONED ROADS AND IN FIELDS. NOTE RUTTED GROUND TO LEFT OF TRACTOR

was set up so that it was approximately 6 inches under water at mean low tide. The flume was extended on a horizontal through the sandbar and into the sea until it was approximately one foot above the floor of the sea. It was held by strong pilings set at 5 foot intervals on each side of the flumes using a water jet from a 500/gal/minute fire pump. An experienced crew of 14 men with dragline, bulldozer, and fire pump could install a 2-drum flume 200 feet long in 4 to 6 days. No high priority materials were used.

Well placed flumes usually lowered the water level 1 to 3 feet and reduced water area by 70 to 80 per cent, particularly when combined with channel dredging above the lagoon end of the flume. The remaining water was more accessible to oiling. Tidal fluctuation and resulting salinification prevented growth of bank vegetation and mosquito breeding for several hundred feet

inland from the flume. Closure by debris and shifting sand made the maintenance of flumes a constant problem.

Flushing Dams. Dams were constructed on suitable streams to build a head of water which, when suddenly released, rushed down the stream bed, washed out larvae and flotage and retarded growth of bank vegetation. Flood waters in the rainy season often washed out these dams; therefore, the gate was removed during this season. Seven flushing dams were constructed on Guadalcanal and 2 on Efate.

Biological Control. Early in 1943, 2 shipments of gambusia were obtained from New Zealand. Rapid propagation of these fish supplied the requirements of all bases. Gambusia were placed in swamps and pools on Espiritu Santo, Russell Islands, and Munda where their chief value was to retard anopheline breeding in marginal territory just beyond the limits of the controlled area. They did well in those sink holes on the Russell Islands where the amount of impounded water was large enough to remain fairly fresh and did not evaporate in the dry season. They were used in wells and cisterns on Efate. It must be emphasized that Gambusia required constant supervision and continual maintenance of the pools and swamps where they were placed. They played a small but distinctly useful part in the total larvicidal program.

7. *Suppressive Medication*

a. *Experiences with atabrine.* Atabrine was eventually established as the best available drug for the suppression of vivax malaria and as a true causal prophylactic of falciparum malaria and so occupied an important but never predominant place in the control program. The use of atabrine for the suppression of malaria was made necessary by the Japanese conquest of the sources of quinine and proved to be a fortunate occurrence, although this fact was not immediately apparent. Medical officers concerned with the discovery of the truth about atabrine were confronted with a great lack of precise information. Little was known about absorption, blood concentration or excretion of the drug, nor was it known whether or not prolonged use would lead either to transient toxicity or to permanent injury.

Throughout 1942 and 1943 there was confusion, disagreement, and uncertainty regarding the use and dosage of atabrine. Standard treatises upon malaria warned that atabrine was a dangerous drug and that its use should be controlled by rigid observation. Directives ordered the routine use of atabrine as the basic anti-malaria drug in order to conserve the rapidly diminishing reserves of quinine. This fostered the suspicion that atabrine was a drug which was necessary rather than desirable. Furthermore, the administration of atabrine was frequently begun on shipboard as troops approached malarious islands, and seasickness, diarrhea and emotional states were attributed to a drug already in doubtful favor. The appearance of the skin, tinted a sickly yellow hue, though harmless, led to the assumption that atabrine was injurious to the liver and this feeling was intensified when infectious jaundice appeared in epidemic proportions among troops taking atabrine. Added distrust of the drug arose

from the development of malaria, for reasons which will be given subsequently, despite the presumed administration of suppressive atabrine. When clinical malaria was treated with atabrine and promptly relapsed, both medical officers and competent non-medical personnel, accustomed to regard quinine as a magic cure for malaria, wondered if atabrine were an adequate substitute.

When the Marines entered Guadalcanal in August 1942 there was wide divergence of authoritative opinion regarding the value and the dangers of atabrine suppressive therapy. Some units took quinine, others took atabrine, and many admittedly took nothing. There was no organization, such as is known to be necessary to supervise the administration of suppressive therapy. Soldiers knew that an attack of malaria might hasten their evacuation to a comfortable and safe rear base and this added to the difficulties in administering suppressive therapy. The malaria rates on Guadalcanal at this period are given in Table I.

The area directives on the subject of suppressive atabrine illustrate growth in knowledge concerning this drug. The following excerpt is quoted from the first directive on suppressive atabrine to appear in the South Pacific Area, September 1942, and is indicative of the paucity of reliable information concerning atabrine and the suppression of malaria at that early date.

"Malaria Prophylaxis. It is recommended that malaria prophylaxis be given as follows: Atabrine is the drug of choice. It should be given in doses of 0.2 gram twice weekly (0.4 gram per week). When atabrine is used it is to be considered advisable, after 3 months, because of slight cumulative effect of the drug to substitute quinine for a period of 1 month. Quinine is given prophylactically in doses of 15 grains daily. This should be continued for one month and then atabrine . . . resumed."

In October of 1943 a new directive maintained the suppressive dose of atabrine at 0.4 gram per week, but the schedule was changed so that the drug was taken as follows; ½ tablet (.05 gram) per day on each day of the week except Sunday when 1 tablet (0.1 gram) was taken. In January 1944 the weekly suppressive dose was increased to 0.6 gram of atabrine per week; 0.1 gram each day except Sunday. In November 1944 the last area directives[36] were issued on this subject and stipulated that 0.7 gram per week be the authorized suppressive dose to be taken as 0.1 gram each day of the week.

The value of atabrine as a suppressive drug was gradually established by clinical observations. It slowly became apparent from the conflicting clinical reports that a few heavily seeded units which had good atabrine discipline actually were suppressing a great share of their malaria so long as they continued atabrine. Thus the 6th Marines reported less than 250 cases of malaria while on atabrine during January and February 1943, on Guadalcanal, as compared with over 2500 cases in May and June, after they had moved to New Zealand and had discontinued the drug. This organization was given loading doses of atabrine prior to arrival on Guadalcanal and 0.6 gram per week while there,

[36] Memorandum #183, Hq., SoPacBaCom, dated 1 November 1944 and ComSoPac Serial 02259 dated 10 November 1944.

with excellent supervision and it was felt that they probably had adequate blood atabrine levels during a period when this was uncommon.

Another organization, the 147th Infantry,[37] took suppressive atabrine of 0.4 gram with poor to fair supervision and had a malaria rate during 5 months on Guadalcanal which ranged around 1000 per 1000 per annum. This rate promptly rose after discontinuation of atabrine in non-malarious Samoa to an average of over 3000 per 1000 per annum for 5 months with peaks as high as 14,000 per 1000 per annum in selected groups. Atabrine was then resumed with excellent supervision and the rate dropped abruptly to well under 100/1000/annum. The history of this organization has been reviewed recently, (14).

This clinical data was confirmed by the careful observations and blood atabrine studies of Baker, Shaffer & Lewis[38] which showed that the development of clinical malaria in troops supposedly taking atabrine suppression was associated almost invariably with extremely low values for serum atabrine concentrations. Further investigation strengthened their opinion that a low atabrine level was almost always due to laxity in taking the prescribed dose of the drug.

This reasoning was confirmed by reports on "Investigations of Atabrine" by the Armored Medical Research Laboratory, Fort Knox, Kentucky, by the work of Shannon (15), by the conclusive clinical and laboratory experiments of Fairley (16), and by other reports (17, 18).

Administration of atabrine for suppression was ordered to be by roster for both officers and men. An officer or a non-commissioned officer was detailed to watch the actual swallowing of the drug by each individual. The roster was checked daily and all individuals who had failed to take the drug were required to report and to take sufficient dosage to equal the amount missed. Men on patrol or other detached duty were given sufficient drug for the period they were to be away and explicit directions for taking it.

As noted above, the dosage which was finally ordered was 0.7 gram weekly, usually given as 0.1 gram daily. An alternative procedure was to give the drug on 2 days a week in doses of 0.4 gram and 0.3 gram. This was done by the 25th Division during the latter part of 1944. This procedure did not give as even a blood level but did facilitate administration and was quite successful.

Many men were quite adept in circumventing these directives usually by palming the drug or by tucking the tablets between teeth and cheek. The only true solution of this disciplinary problem was an educational program to impress every man with the need for and value of the drug and with its harmlessness.

Toxicity: Temporary and minor gastro-intestinal upsets were not uncommon when atabrine was commenced. Information regarding this possibility was publicized in directives and in educational material. Medical officers were advised to continue the drug in lower dosages for individuals so affected. It was found that less than 1 person in 1000 was intolerant of the drug as prescribed. A few cases of skin lesions which simulated lichen planus (19) were noted in

[37] See Graph IX, Paper II.

[38] Unpublished reports to the Surgeon, USAFISPA.

1944. Severe toxic manifestations including exfoliative dermatitis and hepatitis were rare, particularly in those who took only the prescribed dose of 0.7 gram weekly.

b. *Atabrine suppressive therapy, discontinuation of.* Atabrine suppressive therapy was discontinued in lightly seeded troops throughout the South Pacific Area as malaria control measures became advanced enough to permit doing so without danger of significantly increasing malaria rates. This policy was initiated in September 1942, and is further delineated by Memorandum No. 183, Hq., SoPacBaCom, 1 November 1944 and by ComSoPac Serial 02259, dated 10 November 1944. Part of the latter directive is quoted:

"4. Island Commanders are authorized to discontinue atabrine suppressive treatment in selected "lightly seeded" units, upon recommendation of the Island Malariologist, as control measures become sufficiently advanced to permit doing so without interfering with the military effort.

"5. Suppressive treatment may conceal the actual amount of infection or the gradual seeding of a unit. Apparent freedom from malaria may lead to a false sense of security and carelessness in regard to truly preventive measures, such as mosquito control and individual protective measures. Therefore, the eradication of the anopheles mosquito and protective measures against it must be continued with unabated energy."

The events which led to this policy are presented. On Efate a fall in the malaria rate from 2600/1000/annum in April 1942 to 144/1000/annum in September 1942 led to an island order to discontinue atabrine. The rate in these heavily seeded troops rapidly rose to 521/1000/annum in November 1942 and suppression was resumed in all except a few uninfected organizations. This evidence against blanket discontinuation of suppression in highly seeded troops was strengthened in the next few months by unsuccessful attempts to "demalarialize" several heavily infected divisions and regiments (14).[39]

These experiences were supplemented by similar ones on other islands and the following prerequisities for the discontinuation of suppressive atabrine were developed:

(1) Anopheline breeding must be adequately controlled not only on the occupied portion of the base as a whole, but also in the bivouac area of the individual organization. Furthermore, the routine work and training of the organization was not to include night exposure in malarious territory.

(2) Troops must be unseeded or lightly seeded with malaria. This was determined from the history of previous exposure in malarious areas and by a study of the malaria rates of the organization. Those with a history of a high malaria rate were rarely recommended for discontinuation of atabrine even if this rate fell to low levels under suppression. An index to the degree of seeding in troops with an indefinite history was obtained by discontinuing the drug in a small control group. The trend of the rate was more important than the last rate and it was more hazardous to discontinue atabrine in troops with an upward rather than a downward trend, if other factors were equal.

(3) A record of satisfactory malaria discipline was required.

[39] See Graphs VIII and IX, Paper II.

(4) Troops were not removed from atabrine suppression while ground combat was in progress or was threatened; or when they were scheduled for early movement to a combat or malarious area.

The medical officer of an organization in which atabrine was discontinued was advised to make an exception of those men who had had vivax malaria and to continue them on suppressive atabrine. This policy was made official for Army personnel by Medical Circular Letter No. 37, Hq., SoPacBaCom, 10 November 1944, Subject: Treatment of Malaria, which is quoted in part:

"3. *Suppressive Therapy After Clinical Attacks.* In the future it is desired that those individuals who develop vivax or quartan malaria be placed on suppressive atabrine 0.1 gram daily, total 0.7 gram per week, following treatment of clinical attack. These types of malaria tend to recur repeatedly and suppression should be continued as long as the individual is in this command. The purposes of suppressive medication in this connection are therapy in the broad sense and greater military efficiency. Contrarily, falciparum malaria recurs rarely and there is no need to continue suppressive atabrine in individuals with this type of infection."

H. COMMENT

The huge cost of not being prepared to prevent epidemic disease in the tropics which was evidenced by the occurrence of 200,000 attacks of malaria and the loss of many millions of man days in the South Pacific Area alone is a challenge to make certain that such a situation does not recur. The experiences recounted in these papers indicate that we have the knowledge and the equipment necessary to prevent epidemics of insect-borne disease from jeopardizing military operations in the tropics. The problem is one of personnel trained and prepared and determined to make effective use of such technical know-how and facilities.

Six of the factors which contributed to the control of insect-borne diseases in the South Pacific Area will be discussed as follows: the special organization for this purpose; full support from the high command and from officers of all echelons; a joint Army-Navy-Allied organization; centralized control of policy and personnel coupled with decentralization of operations; integration of survey and control activities and an effective training and education program.

1. A special medical department organization for the control of insect-borne diseases was established by the War Department directives of early 1943 which ordered the creation of malaria survey detachments, malaria control detachments and the use of medical officers as malariologists. Under previous, peace time conditions the control of insect-borne diseases had been adequately accomplished as a joint undertaking by the medical inspector of the surgeon's office and the corps of engineers. But under conditions of active warfare both the medical inspector and the corps of engineers had many other responsibilities of high priority and were also handicapped by the lack of technically qualified personnel for the control of insect-borne disease. The response of the War Department to the problem posed by the early epidemics of malaria was the creation of this special organization whose only responsibility was to control malaria and other insect-borne diseases. The number of highly qualified entomologists, engineers and parasitologists who were brought into this organization was an example

of how highly trained technical specialists cooperated to solve the problems of preventive medicine.

2. The full support which the Malaria and Insect Control Organization received from the military command at all levels was of primary importance. The support of the high command was complete and continuous as soon as the importance of malaria to the military effort was apparent. The fact that malaria alone caused the loss of the use of one to two divisions for more than a year was a constant reminder of the need for control. The support from lower echelons was at first spotty and this was partly due to the lack of information about the seriousness of the problem. The widespread support that was forthcoming once the echelons of command were adequately informed is a bright memory.

3. The joint nature of this Army-Navy-Allied organization for the control of insect-borne diseases was a major factor in its success and was a tribute to the vision of the three surgeons concerned and to the first theatre malaria and epidemic control officer. The great economy of this unified organization was continually apparent in the joint utilization of personnel, equipment and supplies, and was of primary importance during the first eighteen months of the organization when personnel shortages and logistical problems were most acute. The joint use of technically trained personnel was the only possible method of adequately spreading the work of the few qualified individuals to cover the great areas which had to be controlled. Each service was able to complement the other. Thus the army malaria control detachments furnished a majority of sanitary engineers, while the Navy was the chief source of supply officers and of rodent control personnel. Likewise, the army eventually provided the majority of the malariologists while advance groups from the Naval Medical Research Unit №2 furnished specialists who rendered invaluable service in methods of application of DDT, taxonomic investigations and many other problems to which base personnel could not devote sufficient time for thorough investigation. The Navy construction battalions provided the bulk of the heavy earth-moving equipment while the army service of supply was the chief purveyor of motor vehicles, sprayers and other insect control supplies. These supplies were channelled where they were most needed; navy and marine stores were requisitioned for army divisions and vice versa. A careful estimate made in July 1944 indicated that this joint use of personnel effected an economy of at least twenty-five per cent as contrasted with the number which would be required to set up parallel Army and Navy organizations on each base.

4. A theatre policy of centralized responsibility for malaria control coupled with decentralization of operations proved to be an effective answer to an insect control problem on eleven malarious bases scattered over fifteen hundred miles of water and to the added problem of shortages of technically trained personnel and of supplies. A rapidly moving amphibious campaign made it imperative that available personnel be placed where the need was greatest. This was often accomplished by leap-frogging malaria control personnel from a rear base to a forward area. Such mobility was obtained for army personnel by a directive which assigned all malariologists, all survey and all control detachments to

the area headquarters rather than the more usual practice of assigning such personnel to the local military command for which they worked. This malaria control personnel was then attached to base and to division commands as required by existing conditions and circumstances and on the recommendation of the area malaria control headquarters. The area malaria and insect control organization made certain that policies for the prevention of insect-borne diseases were area wide in their application; i.e., directives regarding individual protective measures, the formation of anti-malaria details, the use of suppressive atabrine and similar orders were uniform for all forces.

The responsibility for local insect control operations and for local policies was decentralized to each base. But here again the area pattern of centralized responsibility was repeated and the island malaria and insect control officer was accountable for the insect control work of all forces on the island. This officer, army, navy or allied, acted to coordinate the control activities of all services on the base. He and his technical experts were expected to exercise their own initiative and judgment to solve the local problems. The difficulties of command channels which developed under this unusual system have been discussed. This centralization of responsibility for preventing insect-borne diseases in all forces was obviously an unusual and temporary measure applicable at present only under wartime conditions of great urgency.

5. The effective integration of the activities of malaria survey detachments, of malaria control detachments and of malariologists was in the opinion of the authors the greatest single factor in the success of these groups. This coordination was achieved by an area directive[40] which placed responsibility for all insect control work on the malariologist. It is to be assumed that this need for coordination had not been fully envisaged when the organization was originally set up, for the malariologist was a staff officer assigned to the surgeon's office and the malaria survey detachment and malaria control detachment were each small autonomous commands. However, experience was clear that this personnel worked efficiently only when they lived and worked together as a team or group. Survey and control were interdependent. Survey work was academic unless translated directly into control activity. Efficient control work required a preliminary survey followed by regular checking of mosquito breeding by the survey detachment. The correlation of these activities with each other, with the overall training program and with other preventive medicine activities was the responsibility of the malariologist. It is probable that equal or better coordination of these army activities would have resulted had these functions been united under a single command.

The improvisation of an Island Malaria Control Headquarters to coordinate insect control activities on large bases has been described. An excellent method of centralizing responsibility for all preventive medicine activities on such large bases with a heavy troop population was put into effect subsequently on Okinawa through the activation of a provisional battalion headquarters[41] with the island

[40] ComSoPac Serial 002263, 24 October, 1943.
[41] T/O & E.

preventive medicine officer in command. All malariologists, malaria survey detachments, malaria control detachments, medical sanitary companies and rodent control personnel were attached to this battalion. A secondary advantage was the consolidation of reports, requisitions and other administrative details of the small component units. This provisional battalion offered such a satisfactory solution of these administrative problems as to merit more extensive use.

6. The training and education program in insect control work probably paid greater dividents per hour of effort than any other single endeavor. It put many thousands of hands of all degrees of skill to work on insect control, the cumulative effect of which was tremendous. An area training center in malaria and insect control provided excellent training for malariologists and a few others. The inadequacy of this school was in its dependence on the area headquarters staff for its faculty. The school was discontinued when the area malaria control headquarters was moved to the non-malarious theatre headquarters at Noumea, New Caledonia. This school was of such value as to warrant organization with an independent faculty and with a sufficiently mobile organization to move where the greatest number of troops were available for instruction. The other parts of the training and education program deserve no other comment than that they worked smoothly and effectively.

Some additional comments on survey and control activities are pertinent.

7. The need for survey units which are designed for investigational work and having no other duties is adequately discussed in paper III. The need for a parasitological section in these investigational units was amply demonstrated by the contribution of parasitologists in the study of filariasis, schistosomiasis, amoebic dysentery and similar problems. Experience is clear that such investigational work will repay its cost many times over in direct benefit to the military effort.

8. Control activities were handicapped throughout most of the campaign by the long delay between occupancy of a new base and the availability of heavy earth-moving equipment for semi-permanent insect control work. Recommendation was made that suitable earth-moving equipment and position vacancies for operators of this equipment be added to the tables of organization and equipment of medical sanitary companies. The great saving in man days and in troop effectiveness which would result from an early accomplishment of semi-permanent control measures emphasizes the need for some provision whereby such equipment will be directly available to the officer responsible for insect control work.

9. Control measures were characterized by a considerable amount of improvisation in 1942 and 1943 due to the supply shortages. The development of several ingenious substitutes for power sprayers and the manufacture of flumes from empty gasoline drums are examples of this. The use of condemned bangalore torpedoes to replace dynamite resulted from a shortage of the latter explosive and because of the manifest superiority of the bangalore torpedoes for certain types of ditching operation.

Modifications due to the introduction of DDT and special equipment for its

application have been briefly described. Personnel from the South Pacific Area subsequently had an opportunity to utilize airplane application of DDT on a much larger scale on Okinawa, where twenty to forty square miles were sprayed each week. The desirability of both large and small planes for this work was substantiated. It was found that the C-47 type airplane was the best available aircraft for this work because of large load capacity and flying qualities. The presence of a navigator in the crew of the C-47 aided the pilot to fly an exact spray pattern. Moreover, it should be noted that a simple apparatus for the dispersal of DDT solutions by gravity flow with a single outlet under the fuselage gave an adequate coverage at a time when the more elaborate and more efficient spray apparatus described in this paper was not available. The use of DDT solutions on Okinawa exceeded 10,000 gallons daily and required the development of a large scale method of mixing DDT and oil. This was accomplished (22) by using a series of 1200 gallon steel cubes as containers and agitating the DDT mixture with compressed air.

The impregnation of bednets with DDT seems worthy of careful and extensive investigation. The use of this measure in the mounting phase of three divisions from the South Pacific Area indicated the practicability of the procedure. More information is needed about large scale methods of impregnating bednets with DDT, the fire hazard, the duration of insecticidal action and the effect of storage and frequent handling on the latter.

Atabrine as a suppressive drug was of great value but had the obvious defect of hiding the seriousness of the malaria problem and so encouraged laxity in more fundamental methods of control. The great and continued problem of adequate administration of the drug was best solved by giving two doses weekly under careful supervision. The policy of discontinuing atabrine suppression in selected units living in well sanitated areas was consistently followed in the South Pacific Area. It is emphasized again that the control of malaria and of other mosquito-borne diseases was accomplished primarily by insect control.

APPENDIX I

Standard Operating Procedure for Control of Malaria and Other Insect-borne Diseases during a Combat Operation[42]

This Standard Operating Procedure is merely a sample plan adapted to and used during one operation. All such plans should be flexible. One division malaria control group had 4 general plans calling for various degrees of decentralization, the exact plan and details used to be determined by the particular situation.

1. statement of problem

The target for the operation is an area where a flea, louse and parasite infested native population of several hundred persons per square mile is a seed-bed of

[42] Variations of this SOP were published three (3) times, in the South Pacific Area Malaria Training Manual No. 2 revised October 1944; in Preventive Medicine Manual No. 2, HUSAF-POA March 1945, and in The Journal of Military Medicine in The Pacific, September 1945, of which the last and simplest is reproduced.

disease. Fly-borne and water-borne intestinal diseases are likely to be the most immediate disease hazards. Native food is contaminated by the use of human feces for fertilizer and should not be eaten. Dengue fever, malaria and mite-borne typhus are potential dangers. Schistosomiasis (blood fluke disease) adds to the risk of drinking or bathing in untreated water.

2. MOUNTING PHASE

a. All personnel will again be trained in individual measures to protect against mosquito and mite bites. Water and food discipline will be emphasized. Fly control measures will be reviewed, particularly the use of DDT solutions and of sodium arsenite solutions to spray corpses. Officers will review the importance of campsite selection to avoid proximity to infected natives and to breeding places of disease carrying insects.

b. Bednets of all personnel will be sprayed with a five (5) per cent solution of DDT in kerosene.

c. Each man will be provided with 2 uniforms and 1 blanket impregnated with dimethylphthalate as outlined in TB Med 121 dated December 1944. Measures in b and c will be carried out as short a time before embarkation as possible.

d. Immunization records will be checked and the necessary booster doses will be given.

e. Suppressive atabrine will be given to all personnel as outlined in TB Med 65, dated July 3, 1944, beginning 3 weeks before D-Day.

f. Each individual will be provided with:

Bar, mosquito or hammock, jungle, complete	1
Repellent insect, 2 oz. bottle	2
Atabrine tablets, 0.1 Gm	30
Insecticide, powder, louse, 2 oz. can	1

g. Each organization will be issued 30 days supply of the following items which will be conspicuously marked and carried with the organization so as to be readily available:

Insecticide, powder, louse, 2 oz. can	100 per 100 men
Repellent, 2 oz. bottles	300 per 100 men
Sprayer, liquid, insecticide, continuous spray, 2 quart	1 per 100 men
Sprayer, oil knapsack type	1 per 100 men
Diesel oil No. 2, 55 gallon drum with 5% DDT added	1 per sprayer oil knapsack type
Atabrine tablets, 0.1 Gm	4000 per 100 men
Insecticide, freon-aerosol, 1 lb. dispenser	30 per 100 men

3. COMBAT PHASE

a. The malariologist, with the entomologist and parasitologist will provide the surgeon with an insect survey and an estimate of the malaria and insect-borne disease hazard as rapidly as feasible after D-Day, with subsequent estimates as determined by current conditions and needs.

b. Fly control will be done by hand spraying of dead bodies, with 5 per cent DDT solution or with 1 per cent sodium arsenite solution, and by proper care of human waste and garbage, see par. 4.

c. Anti-mosquito measures will be carried out by temporary spray teams as outlined in par. 4. The application of DDT residual effect solution to native dwellings will be emphasized. A single spraying of such buildings with DDT not only will kill all mosquitoes, flies and fleas in the building but will continue to kill them as they come in contact with treated walls for several months.

d. Airplane spraying of DDT will be available about D plus 10. Requests for airplane spraying will be forwarded to the surgeon and will describe the area to be sprayed with an accompanying contour map or grid map. The nature of the insect problem with exact entomological data should be given and an estimate of the need for repeat spraying.

4. TEMPORARY SPRAY TEAMS FOR EACH REGIMENT

a. Each regimental commander will immediately form a temporary spray team comprising 20 men, one man drawn from the insect and rodent control detail of each company. These spray teams will be assisted by 2 technicians, who will be temporarily attached from the Malaria Survey and Control Detachments assigned to Army, Corps or Division. Each regimental spray team will be quartered with its regimental headquarters company for the combat period. The work of these spray teams will be supervised by the Divisional Medical Inspector and by personnel from Malaria and Insect-Borne Disease Control Groups.

b. Duties of These Spray Teams:

In amphibious operations these spray teams will go ashore with the headquarters to which they are attached and begin fly and mosquito control work. Each team will carry out the following measures in the rear of combat lines.

(1) Fly Control. Dead bodies will be sprayed with 5 per cent DDT solution or 1 per cent sodium arsenite solution. Straddle trenches and pit latrines will be sprayed with 5 per cent DDT at the rate of 1 pint per hole twice a week.

(2) Spraying of dwellings and other temporary mosquito control measures in areas of headquarters, medical facilities, supply stations and along communication lines.

c. Equipment of These Spray Teams.

Every man will be equipped with a sprayer for DDT solution. Technicians from Division malaria and insect control groups will carry a dipper for sampling larva populations and preliminary spot maps. Each spray team will carry one week's supply of DDT solution prepared in advance and 3 weeks' supply of DDT powder, dissolving. Each spray team should be equipped with a power sprayer.

d. The Temporary Spray Teams are formed for the period of active operation only. As soon as conditions become stabilized and when designed by the division surgeon, this personnel will return to routine control measures of the company insect and rodent control details.

e. No duties that interfere with their malaria and insect control functions will be assigned to the above personnel.

5. Individual protective measures against mosquito-borne diseases, mite-borne typhus, and schistosomiasis will be carried out by all division personnel as directed.

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MALARIA AND OTHER INSECT-BORNE DISEASES IN THE SOUTH PACIFIC CAMPAIGN

1942–1945

II. Epidemiology of Insect Borne Diseases in Army Troops

W. G. DOWNS,[1] P. A. HARPER[2] and E. T. LISANSKY[3]

Table I and II and Graphs I through XII present data on the incidence of malaria in military personnel in the South Pacific Campaign. Table I and Graphs I through VII pertain to all Army, Navy, Marine and Allied forces on malarious bases. Table II shows the malaria rates for all army personnel on both malarious and non malarious bases; and Graphs VIII through XII show the malaria rates in selected units during their period of duty in the South Pacific Area. The graphs show total rates, primary rates and readmission rates.

The true malaria transmission rate was concealed by suppressive therapy. A low malaria rate was obviously not an index of malaria transmission on a base where all troops were taking suppressive medication. Fortunately the policy of discontinuing suppression in lightly seeded troops provided an indication of the extent of disease transmission. Data for these individual units are not given but a line at the bottom of each graph indicates the percent of troops taking quinacrine hydrochloride (atabrine) suppressive therapy.

The background and other history of these malaria rates is given in papers I, III and IV.

A. Explanation of Graphs and History of Individual Bases

Graph I, Efate, New Hebrides[4]

Efate was the first malarious base to be occupied in the South Pacific, March 1942. Troops were hurriedly sent to this island to build an airfield and forestall the southward advance of the Japanese and were bivouaced in an area which was adjacent to a native camp and where anophelines were numerous. Supplies of antimalarial drugs were inadequate, bed nets were not available for all, and night work was necessary. In April 1942 malaria rates reached 2678 per 1000 per annum. In May about 50% of the troops were directed to take quinine 0.33 grams daily, later increased to 0.66 grams. Even the latter dosage did not provide adequate suppression and in July some units began to take quinacrine hydrochloride 0.4 grams weekly. Malaria control personnel consisting of one officer and three enlisted men arrived on 28 July 1942. Malaria rates decreased

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[4] Graphs I through XII were originally prepared by Major C. D. Speck, M. C. from data sent monthly to area headquarters by each local malaria control group and first published by Harper et al: Malaria and Epidemic Control in the South Pacific Area.

TABLE I

Malaria rates in all forces in South Pacific—Army, Navy, Marine and Allied

Rate per thousand per annum on malarious bases

BASE	JAN '42		FEB '42		MAR, '42		APR '42		MAY '42		JUNE '42	
	Orig adm	All adm	Orig adm	All adm	Orig adm	All adm	Orig adm	All adm	Orig adm	All adm	Orig adm	All adm
Efate							2632	2678	838	982	667	915
	JULY '42		AUG '42		SEPT '42		OCT '42		NOV '42		DEC '42	
Efate	354	518	113	209	84	144	135	289	304	520	177	377
Santo					36	36	55	59	30	82	137	142
Guadalcanal				14		177		1664		1781		972
	JAN '43		FEB '43		MAR '43		APR '43		MAY '43		JUNE '43	
Efate	123	290	207	342	163	217	130	179	118	176	72	145
Santo	219	255	208	253	150	181	160	191	109	130	62	85
Guadalcanal		1169		878		1052		1182		900	396	636
Tulagi	229	311	281	409	305	389	352	516	396	593	249	486
Russells					281	281	194	204	239	271	283	324
	JULY '43		AUG '43		SEPT '43		OCT '43		NOV '43		DEC '43	
Efate	66	128	37	76	58	165	20	92	10	83	18	84
Santo	58	98	35	68	20	51	40	83	16	53	17	41
Guadalcanal	342	608	142	263	181	287	124	230	91	206	71	149
Tulagi	230	417	240	373	214	363	215	366	98	211	97	163
Russells	328	395	261	346	146	258	80	137	46	95	57	99
Munda		416		329		629		625		504	123	258
Vella-Lavella						96		94	42	83	43	104
Bougainville									54	58	94	95
	JAN '44		FEB '44		MAR '44		APR '44		MAY '44		JUNE '44	
Efate	25	122	14	100	20	79	11	69	10	45	6	37
Santo	20	53	7	32	7	28	4	16	3	16	8	19
Guadalcanal	130	200	74	126	59	124	50	99	48	95	30	75
Tulagi	93	167	91	194	85	177	34	115	27	99	32	107
Russells	69	105	129	158	110	189	66	142	71	170	41	104
Munda	107	200	57	114	30	65	22	52	20	51	*	
Vella-Lavella	67	166	78	160	129	282	133	329	15	54	*	
Bougainville	35	119	37	104	37	83	61	103	66	104	*	
Treasury	11	12	6	21	6	15	5	26	15	34	*	
Green					24	37	29	41	42	62	*	
Emiru							58	111	23	46	*	
	JULY '44		AUG '44		SEPT '44		OCT '44		NOV '44		DEC '44	
Efate	2	20	4	32	8	30	0	27	0	0	0	0
Santo	2	15	1	8	1	5	1	4	0	2	0	3
Guadalcanal	33	66	20	58	28	63	22	51	18	43	11	29
Tulagi	29	86	9	51	16	58	11	37	14	53	12	26
Russells	30	88	12	57	11	45	6	30	10	31	12	29
	JAN '45		FEB '45		MAR '45		APR '45		MAY '45		JUNE '45	
Efate	0	0	128	128†	0	0	0	0	0	0	0	0
Santo	2	4	4	5	3	4	3	3	7	8	2	4
Guadalcanal	18	35	14	25	6	14	8	19	13	19	6	9
Tulagi	38	59	15	28	73	99	27	40	54	66	13	26
Russells	16	37	18	40	6	15	9	21	5	10	8	8

* Base transferred to South West Pacific Area.

† One case.

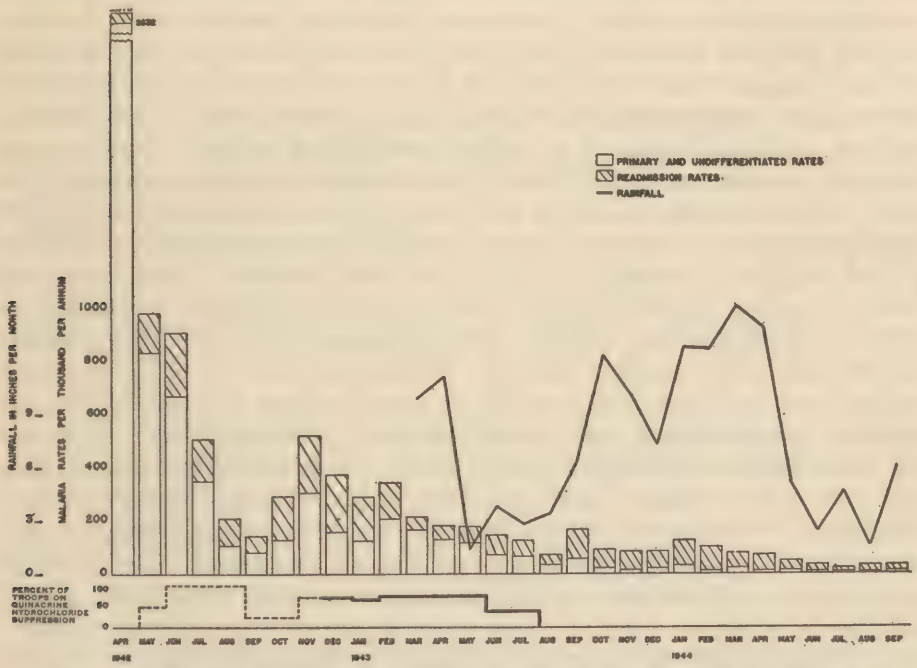
TABLE II*

Malaria rates in army personnel in South Pacific malarious and non-malarious bases

	1942		1943		1944	
	Cases	Rate per 1000 per annum	Cases	Rate per 1000 per annum	Cases	Rate per 1000 per annum
January			1818	172	2875	166
February			1903	210	2717	152
March			2474	253	3444	167
April			4596	371	1980	112
May			3396	347	2143	124
June	290	77	6596	626	1539	84
July	320	57	8107	593	632	63
August	109	24	7494	696	†	
September	184	19	8324	578		
October	190	33	7384	528		
November	238	38	5414	400		
December	480	67	3779	252		
Total	1811	38	61,285	427		

* Data supplied by tropical Disease Control Division, office of Surgeon General; compiled from 86 AB reports.

† The South Pacific Area became part of the Pacific Ocean Area, later called the Middle Pacific Area, at this time.



GRAPH I. EFATE. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES.
(See Table I for data from November 1944 through June 1945)

rapidly from the April peak because of the initiation of insect control measures, suppressive therapy and the onset of the dry season. Quinacrine was supplied to natives for suppression of parasitemia; native huts near troops were sprayed daily with a pyrethrum spray; and finally, nearly a year after the original epidemic, the largest native labor camp, "Riserville", was relocated a safe distance from troops. Antimosquito work was well organized by early 1943. Heavy equipment for semipermanent malaria control projects was not available until 16 months after occupation.

The low total rate of 144 per 1000 per anum in September 1942 induced Army and Navy units to discontinue suppressive therapy. When the November rate rose to 520 per 1000 per annum, suppressive therapy was resumed in all except certain Navy personnel who were lightly seeded and living in screened quarters. Many of the heavily seeded units left Efate in 1943 and the remaining troops were withdrawn from poorly controlled areas. Quinacrine suppression was discontinued in all troops in mid-1943 and the subsequent low rates are unmodified by drug suppression.

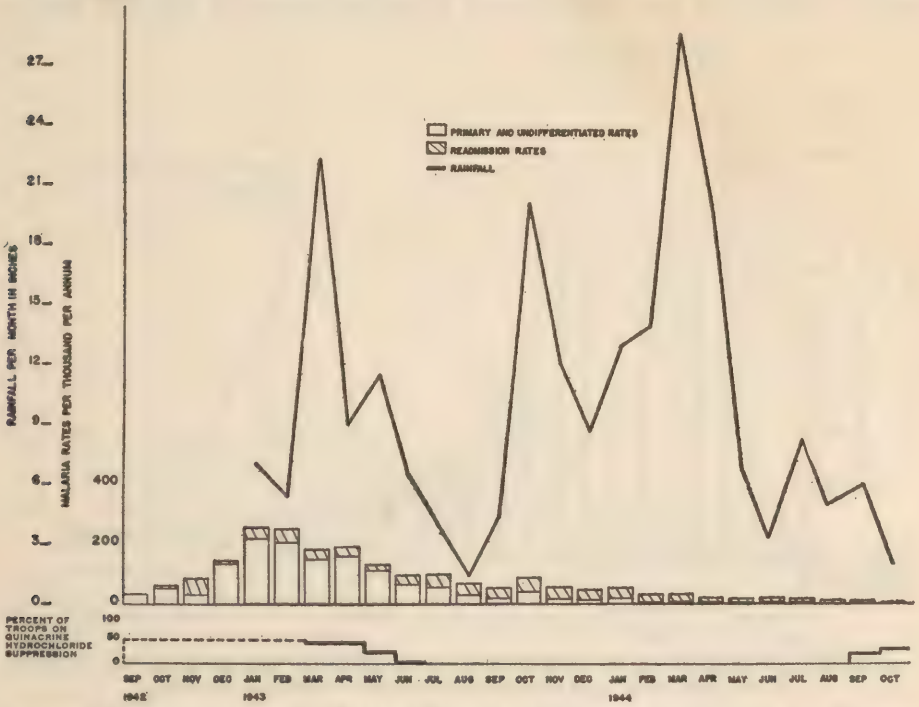
Graph II, Espiritu Santo

The unopposed occupation of this base was made at the beginning of the dry season in May 1942. There was minimal mosquito breeding near the original campsites and until September of that year no cases of malaria were reported even though drug suppression was not practiced. In September, October and November 1942 incoming troops were camped near heavily seeded natives in areas of anopheline breeding. Quinacrine suppression was ordered for the more exposed personnel and rates did not rise above 256 per 1000 per annum during the rainy season of early 1943. A Base Malaria Control Group consisting of 2 officers and 8 enlisted men was established in September 1942. Troop concentrations were kept separated as far as possible from natives. Natives were started on suppressive therapy in early 1943, and native huts were sprayed regularly with pyrethrum insecticide from early 1943 to mid-1944, when DDT residual spraying was started. By mid-1943 an extensive and effective malaria control program consisting of larvicidal and semi-permanent control measures was in operation, and following this it was unusual to find adult anophelines in the main occupied areas. In July 1943 suppressive therapy was discontinued for troops in well controlled localities. Despite adequate control in the main occupied area, outlying regions on the base continued to be highly malarious and troops on outpost duty became heavily infected. Rates for Espiritu Santo are not comparable with rates from other South Pacific malarious bases because only cases occurring in local units and of local origin were considered in the computations. An undetermined small amount of malaria which actually was contracted on Espiritu Santo plus a larger amount of malaria occurring in transient personnel and representing malaria contracted elsewhere, was therefore never reported on this base. On other bases, all cases of malaria were usually included in the determination of local malaria rates, regardless of the origin of the infection. Excepted from this policy were those patients who developed malaria on

a forward base and who were temporarily housed in hospitals on successive rear bases during evacuation to a non-malarious island.

Graph III, Guadalcanal

The campaign for the Solomon Islands began in August 1942 with the invasion of Guadalcanal by Marine units. These forces were supplemented in October by Army units. Antimalaria supplies were at first unavailable or inadequate, and no significant amount of mosquito control work was accomplished. There were only a few cases of malaria in August and September. However, conditions

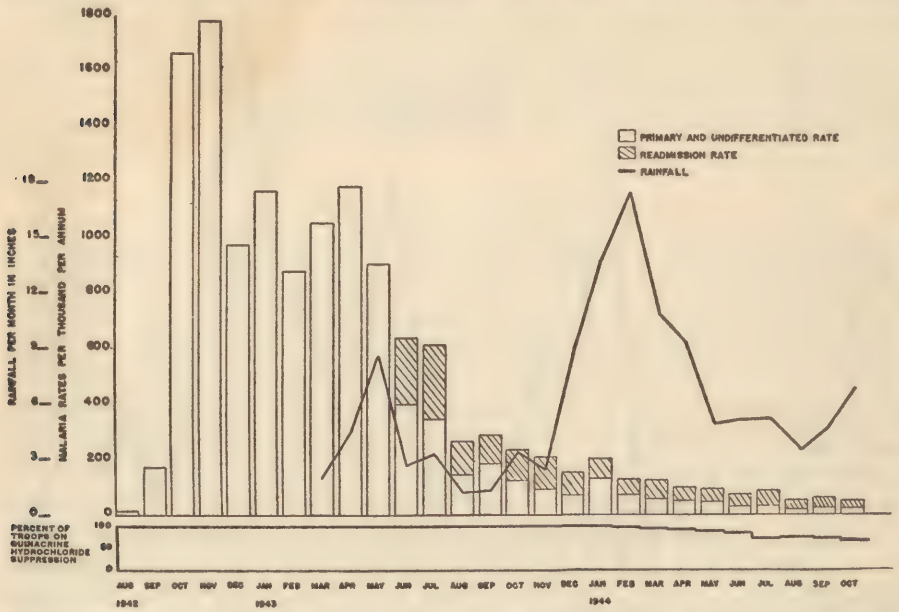


GRAPH II. ESPIRITU SANTO. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES. (Not comparable with rates of other bases. See text). (See Table I for data from November 1944 through June 1945)

were ideal for the breeding of enormous numbers of mosquitoes during this period. The flat alluvial plain of the contested area was traversed by more than 40 rivers and small streams. There were over 50 lagoons. The soil was a heavy clay which was difficult to drain. Mosquito breeding areas were increased by the multitude of shell holes and fox holes, and ruts caused by heavy vehicles. It has been estimated that "man made" breeding places accounted for over 50% of the mosquito breeding during the first year of occupation. The disease became epidemic in November with a peak case rate of 1800 per 1000 per annum in this month. Epidemic conditions prevailed for at least 9 months. It is probable that of the estimated 100,000 cases of malaria contracted in the South

Pacific area more than three-fifths of the total number were contracted on Guadalcanal, largely during the period from November 1942 to August 1943. The malaria rate decreased to less than 200 per 1000 per annum by December 1943 and continued to fall in spite of a steady increase in the percent of troops released from suppressive medication.

A Base Malaria Control Group, (initially composed of Navy personnel, later becoming a combined service group) of 2 officers and 8 enlisted men was established in November 1942. This organization in time expanded greatly, and the base received by far the largest amount of antimalaria effort of any island in the area. Control work was well advanced by the latter part of 1943 and thence-

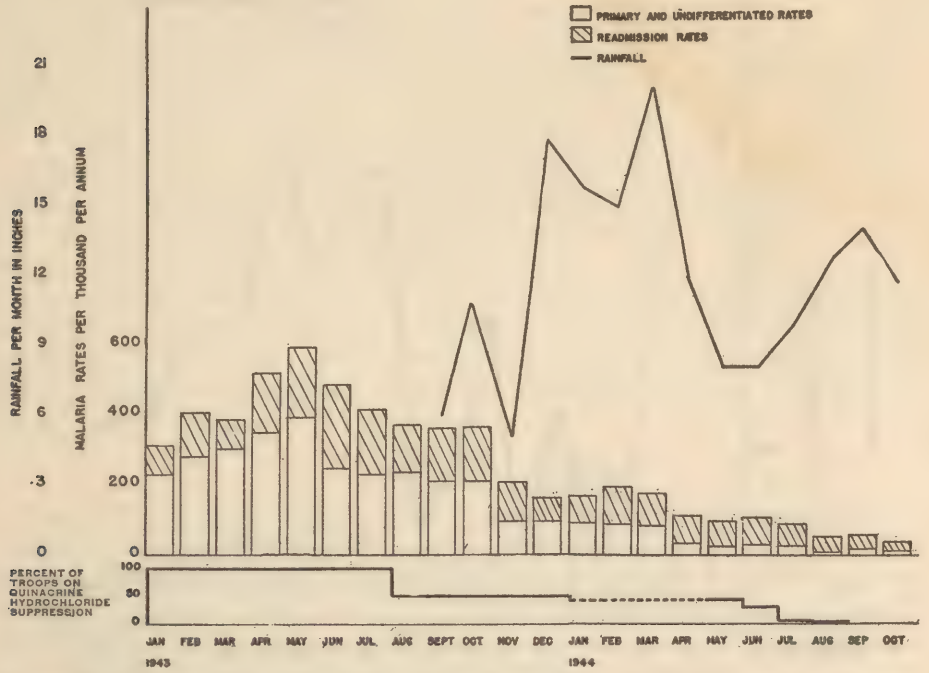


GRAPH III. GUADALCANAL. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES. (See Table I for data from November 1944 through June 1945)

forth adult anophelines were difficult to find except in a few marginal areas and during sporadic infestations in the central areas.

Factors contributing to the control of epidemic malaria on Guadalcanal are so inextricably intertwined that it is impossible to examine them individually and to assess accurately the relative importance of each. The most important factor was the extensive malaria control work, both larvicidal and drainage, which was accomplished. Other important factors included quinacrine suppressive therapy as an aid in lowering rates in heavily seeded troops; carefully supervised handling of natives, including administration of suppressive treatment and mass therapy, spraying of native dwellings, the removal of labor camps from troop areas by August 1944; the improvement of living conditions for troops, including an eventual great increase in the number of screened dwellings; and extensive troop education in personal malaria preventive measures.

A significant development in November 1943 was the establishment of a troop bivouac area of about 90 square miles, where mosquito control was continually exercised. No organization bivouaced outside this area without special permission. Troops staging on this base were given approved locations for their temporary camps, thus eliminating a very prominent source of malaria during the early Solomon's campaign. During this early period troops who had staged on Guadalcanal in uncontrolled areas for only a few days and then moved on to another base, would often have severe malaria outbreaks largely traceable to their exposure on Guadalcanal.



GRAPH IV. TULAGI—FLORIDA. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES. (See Table I for data from November 1944 through June 1945)

In February 1944, the discontinuance of suppressive therapy was begun in lightly seeded units. By October 1944 about 26% of the troops had been allowed to discontinue quinacrine and the island total malaria rate was only 51 per 1000 per annum. The malaria rate continued to decrease and by June 1945 over 75% of troops were released from suppression.

Graph IV, Tulagi-Florida

American forces landed in the Florida group of islands against brief but spirited Japanese opposition in August 1942. Small groups of troops were widely scattered and antimalaria supplies were inadequate. No rates are available for the period prior to January 1943, at which time malaria control activities were

instituted by a Navy malaria control group. In one organization of 237 men the malaria rate in December 1942 reached 2004 per 1000 per annum while the group was supposedly taking 0.4 grams of quinacrine weekly. The maximum recorded rate for this entire group of small bases was 593 per 1000 per annum in May 1943. Most of the cases occurred in a few units in poorly controlled areas and therefore drug suppression was discontinued in about half the troops in August

GRAPH V. RUSSELLS. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES.
(See Table I for data from November 1944 through June 1945)

1943. In September 1944 quinacrine was discontinued in all personnel when the total rate on this base was 58 per 1000 per annum.

Effective control work played a major part in reducing epidemic malaria on these small bases. The work was made difficult and complex by the scattered position of the small groups. Several of the troop units and areas were accessible only by boat.

Graph V, Russell Islands

The 43rd Division made initial landings on Banika Island in the Russell group in late February 1943. This division had been previously seeded with malaria

on Guadalcanal and the monthly rate for March was 281 per 1000 per annum. There were neither natives nor Japanese on Banika or Pavuvu, the two main islands occupied. Mosquito breeding sites were numerous on both islands, and hundreds of small round ponds, about thirty feet in diameter, were scattered throughout the coconut plantations.

A base Malaria Control Unit consisting of one officer and three enlisted men arrived on March 3, 1943, to find a serious outbreak of *P. falciparum* malaria among troops who had been resident less than two weeks on the base, and incoming units from Guadalcanal showed the same picture. Rates of 200–400 per 1000 per annum continued for many months, in spite of quinacrine suppressive therapy of 0.4 grams per week which was poorly supervised.

Although no natives were originally present on Banika Island, 600 labor corps natives arrived in late 1943. The area occupied by them was kept under adequate control; huts were sprayed, suppressive therapy was administered and natives were restricted to their own camp area after 1800 hours.

For many months control measures were limited to larvicidal work, and troop areas were in large part well controlled. No significant amount of heavy equipment was used for more than a year after occupation; during 1944 heavy equipment projects were about 90% completed.

Discontinuance of suppressive therapy in selected lightly seeded units began in August 1943, and permitted a malaria peak of 189 per 1000 per annum in March 1944. By October 1944, improvement of control work with an increase in the proportion of troops taking quinacrine produced a decline in the rate to 30 per 1000 per annum.

Graph VI, Munda, New Georgia

The 43rd Division invaded Rendova Island in the New Georgia group on July 1, 1943. Small groups also landed at Wickham Anchorage, at Segi and at Viru Harbor, all of these being on New Georgia. The main invasion of New Georgia by the 43rd Division, later joined by the 37th and 25th Divisions took place in the Munda area in mid-July. A Malaria Control Group landed on Rendova on July 11, 1943 and moved to the main base at Munda in August.

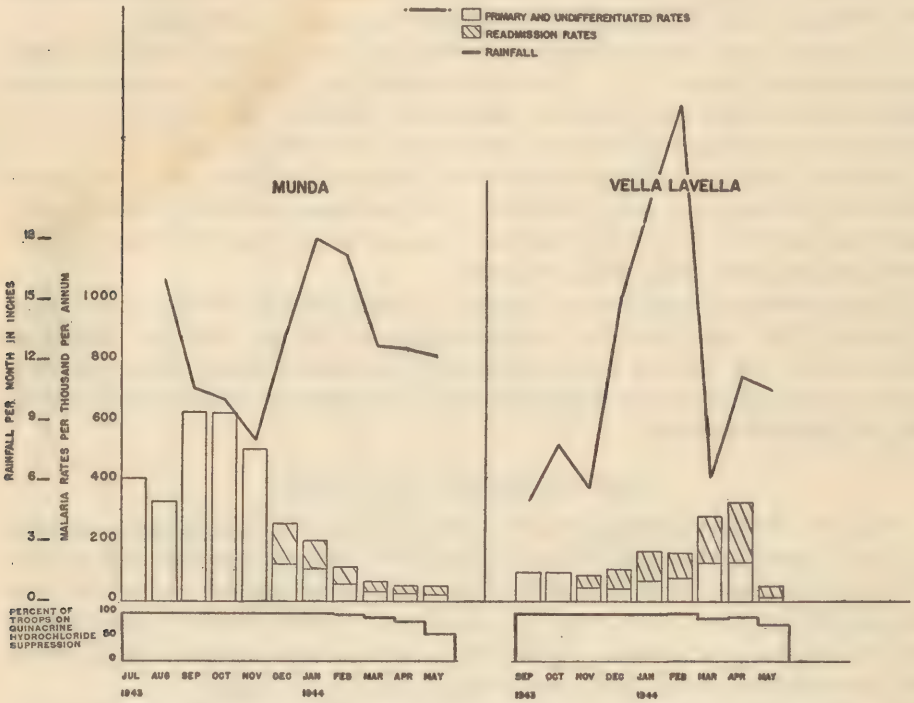
Heavy combat during the first two months resulted in many shell and bomb craters, ruts and similar sources of man made malaria. The seed bed consisted of Japs and Allied troops previously infected on other bases. All Allied troops took quinacrine suppression, 0.4 grams per week, poorly supervised. For the first time in South Pacific campaigns, there was a small supply of insect repellent and aerosol bombs.

Rendova presented a serious anopheline breeding problem. It was temporarily controlled for a month and then abandoned. New Georgia presented difficulties because of innumerable small breeding areas, bomb craters and ruts, scattered over a wide area. Early control efforts with insufficient personnel, equipment and transportation could only partially cope with the problem, but no serious difficulties were encountered when more personnel and equipment became available in October 1943.

Control groups were also established at Segi and at Ondongga, on New Georgia, to cope with insect-borne diseases in small numbers of troops. Local camp-site control was the main effort on such islands as Baangam, Arundel, Roviana, Sasavelo, Bau, Kokorana, Barauna and Kolombangara.

A native labor camp was set up on an offshore island and presented no problem.

Malaria rates rose to 629 per 1000 per annum in September 1943, with the heavily seeded 25th Division showing a rate of 1000–1500 per 1000 per annum. Shortly after this peak a large proportion of heavily seeded units left the base, and by May 1944 rates had dropped to 51 per 1000 per annum.



GRAPH VI. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES
(Bases transferred to SWPA 15 June 1944)

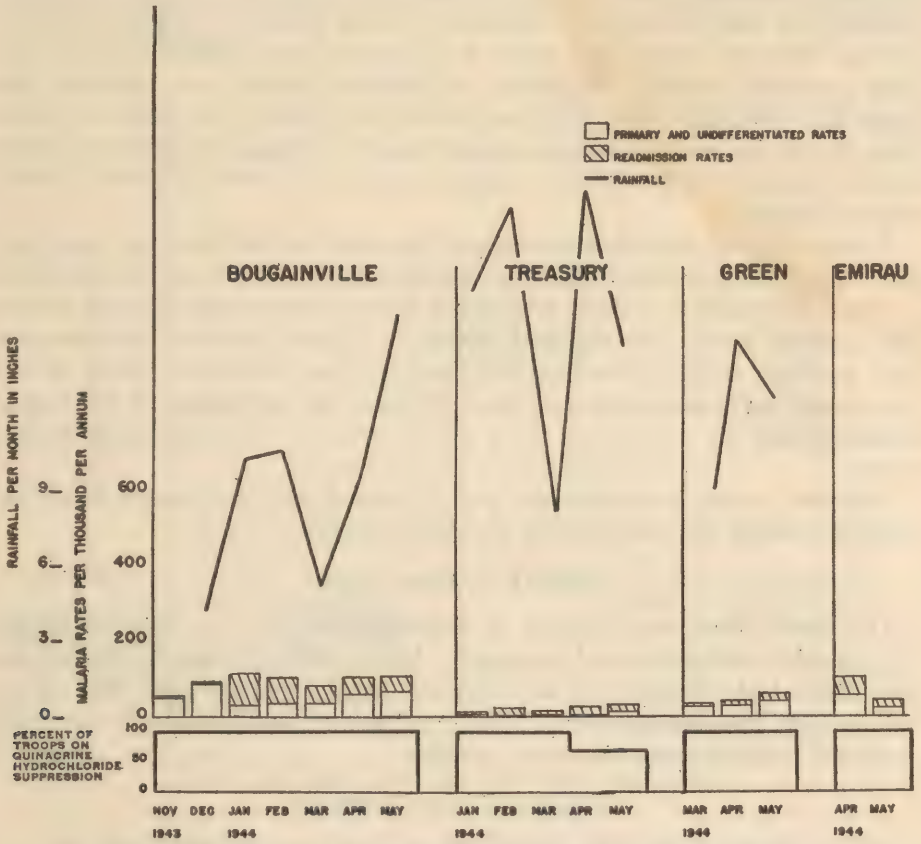
Graph VI, Vella Lavella

Vella Lavella was occupied in August 1943 by New Zealand troops aided by a small American force. The malaria control unit attached to the 3rd New Zealand Division, consisting of 4 officers and 33 enlisted men, arrived with the division. In addition, a Navy control group was also present, working in areas occupied by U. S. troops. Most of the malaria cases seen on this base occurred in a single Marine Defense Battalion which had been heavily seeded on Efate in 1942. By April 1944 the rate in this battalion was 964 per 1000 per annum but with improved drug suppression fell to 114 in May, as compared with an island rate of 54 per 1000 per annum. Forces on Vella Lavella were dispersed over a

long stretch of coast line, and the low rates in the New Zealand Division (previously unseeded) are a tribute to their malaria discipline and the efficient larviciding program maintained.

Graph VII, Treasury Island

This small island was occupied by New Zealand troops in October 1943 and a section of the New Zealand malaria control group proceeded there. A small



GRAPH VII. MALARIA RATES PER THOUSAND PER ANNUM, ALL FORCES
(Bases transferred to SWPA 15 June 1944)

Navy control group also was established on Treasury. All natives were evacuated from Treasury to Mono. An early larvicidal program was followed in early 1944 by drainage of the few swamps present.

Graph VII, Bougainville

Landings were made at Empress Augusta Bay, an almost uninhabited area, in November 1943. Fully organized malaria control groups went in with the combat divisions; a Navy Malaria Control Group with the 3rd Marine Division

and an Army Malaria Control Group with the Americal and the 37th Divisions. In January 1944 a Base Malaria Control Group was established for service troops. The occupied area was so difficult to approach from other Jap held parts of the island that the main ground combat did not take place until March 1944, although the early period of Marine occupation was characterized by bitter fighting in dense jungle and swamp. There were extensive swamps near the beach and our troops established camps at some distance from the beach, where the underlying sandy soil proved to be very easy to drain. Control work was started early and malaria never became a serious problem. The peak rate of 119 per 1000 per annum was recorded in January 1944. Many of the troops were previously seeded. Quinacrine suppressive therapy was universal, 0.6 gram per week, and while far from perfectly supervised, was better observed than during any previous major combat period. Adequate supplies of insect repellent and aerosol bombs were available, and use, at least of aerosol bombs, was widespread.

A large group of natives was quartered almost in the middle of the troop concentration, but in an area which was carefully supervised and rigidly controlled.

Minor outbreaks of malaria occurred in troops on perimeter defense, and in units making sorties into Jap held territory. It was interesting to observe a high incidence of *P. falciparum* infections in these outbreaks. Most of the cases occurring in controlled areas were *P. vivax*, and the history of these cases indicated that the majority of them were relapses of infections acquired elsewhere.

Mosquito control measures were well advanced and adult anophelines were difficult to find in the occupied area after the first quarter of 1944.

Graph VII, Green Island

This small island was occupied in February 1944 by New Zealand troops, with attached malaria control personnel. Later, a Base Malaria Control Group was established. There were few anopheline breeding sites and 90% of the natives were removed to another island. Effective control work was instituted early and malaria never became a problem.

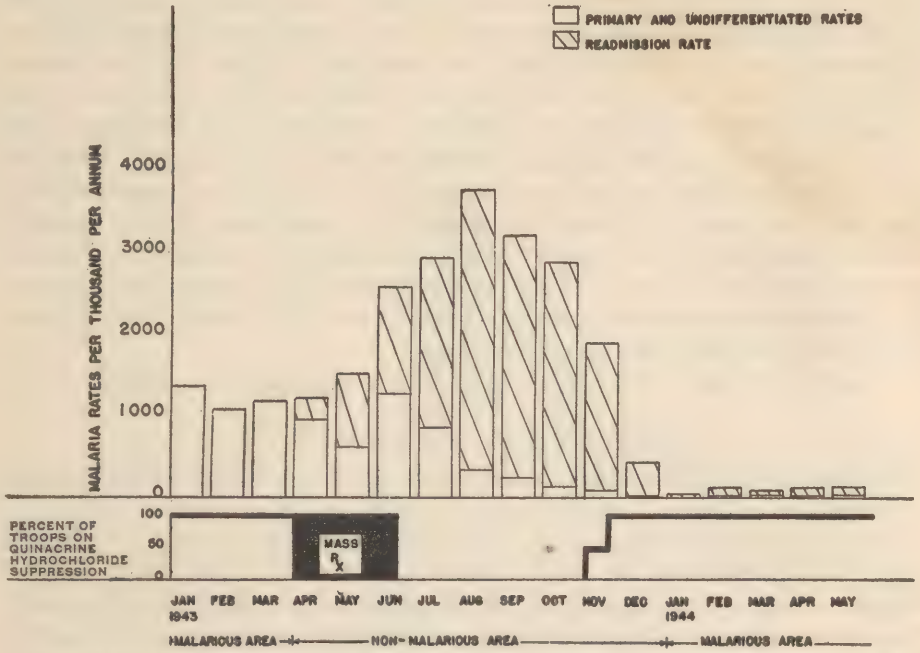
Graph VII, Emirau Island

This small island of the St. Matthias group was occupied in March 1944. A Malaria Control Group accompanied occupying forces and a very effective control program was instituted early. Even heavy equipment drainage projects were completed in three months. 220 natives on this island were relocated on a neighboring island. Although extensive anopheline breeding areas existed on Emirau, early larvicidal work followed by drainage of all swamps prevented malaria from becoming epidemic.

In June 1944 the bases of New Georgia, Vella Lavella, Treasury, Bougainville, Green and Emirau were transferred to the South West Pacific theater and malaria statistics are not available for those bases after that date. However, by this time all of these bases had well organized malaria control organizations and epidemic malaria had ceased to exist among troops.

Non-Malarious Bases

Malaria control personnel in New Zealand, New Caledonia, Samoa and Bora Bora aided in demalarialization programs carried out in troops sent to these areas for rest and rehabilitation. Several of the hospitals in New Zealand, Fiji and New Caledonia also assisted or in some cases carried a major part of this program. Laboratory diagnostic centers were established and statistical data was accumulated on malaria in the troops. In Samoa and Bora Bora the malaria control organizations aided and supervised an antimosquito program directed against the vector of filariasis.



GRAPH VIII. AMERICAN INFANTRY DIVISION. MALARIA RATES PER THOUSAND PER ANNUM IN RELATION TO EXPOSURE AND TO THERAPY
Scale differs from Graphs I–VII

B. MALARIA EXPERIENCE OF CERTAIN ARMY UNITS

Graph VIII, Americal Division

This division moved by echelons to Guadalcanal in October, November and December 1942. In March 1943 it was transferred to Fiji for "demalarialization" and rehabilitation. While on Guadalcanal there was little or no field control, no repellents or aerosol bombs, and very little malaria discipline. The troops lived and fought in areas where malaria was epidemic. Quinacrine suppressive therapy, 0.4 gram per week, was prescribed, but the extent of its use has been questioned and cannot now be determined. The monthly malaria rates were as high as 1358 per 1000 per annum while in the combat zone. After evacua-

tion to Fiji, mass treatment with quinacrine and plasmochin was given to the entire division from April to June. Plasmochin was discontinued in those who did not tolerate it and additional quinacrine was given this group. After this mass therapy, no antimalarial drugs were administered except to those having clinical attacks of malaria. With the discontinuance of drugs and in spite of the previously administered mass therapy, the monthly rate rose in August to a peak of 3760 per 1000 per annum and in October was still at the high level of 2880 per 1000 per annum. On November 1, when the division was alerted for return to a combat area, quinacrine suppressive therapy was gradually resumed, 0.4 gram per week, and increased to 0.6 gram per week in mid-December. The malaria rate fell to 43 per 1000 per annum in January, a dramatic demonstration of the suppressive power of quinacrine. After 5 months of combat duty on Bougainville the total rate for May 1944 was only 112 per 1000 per annum. A Malaria Control Group, (a malariologist, a malaria survey detachment and a malaria control detachment) was attached to this division in December 1943.

The changes in malaria parasite species partition which occurred after this division left the malarious area was interesting. *P. falciparum* comprised more than fifty per cent of all malaria reported on Guadalcanal during January, February and March 1943, and *P. vivax* comprised about twenty-five per cent of cases, Figure I, Paper IV. This predominance of P. falciparum continued for a few weeks after arrival in Fiji and was then rapidly reversed and P. vivax constituted practically all subsequent cases.

A study of the effects of malaria on this division is given by Tumulty et al. (1).

Graph IX, 147th Infantry Regiment

A presentation of the early history and attempted "demalarialization" of this regiment in Upolu, British Samoa, has been published recently (2).

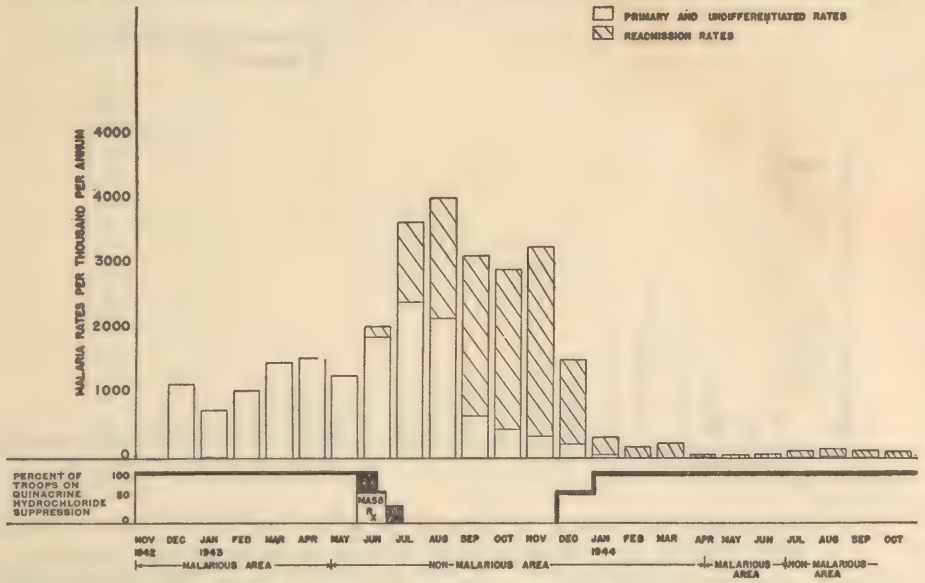
The 1st Battalion of this regiment disembarked at Guadalcanal on 4 November 1942, the 3rd Battalion on 29 November 1942, and the 2nd Battalion on 7 February 1943. The entire group departed from Guadalcanal for Samoa in May 1943. Except for the 1st Battalion which used quinine during November, suppression was with quinacrine 0.4 gram per week, but was not closely supervised until late March.

The morning sick reports while on Guadalcanal showed malaria in 48 percent of the regiment, and monthly rates for the disease during this period reached a peak of 1558 per 1000 per annum in April, although most of the diagnoses were unconfirmed by blood smear examination.

"Demalarialization" was begun in Samoa in May 1943. Four plans were used: (1) quinacrine mass therapy immediately, (2) quinacrine mass therapy after a ten day interval of no medication, (3) mass treatment with both quinacrine and plasmochin, and (4) no mass therapy. Suppressive medication was then discontinued in all of these groups and clinical cases were treated as they occurred. The termination of mass therapy was staggered so that while peak rates in the different groups exceeded 14,000 per 1000 per annum, yet the rates of the regiment as a whole during this period did not exceed 4090 per 1000 per annum.

The 2nd Battalion was on Wallis Island from October 1943 to January 1944, when all three battalions were moved to New Caledonia. Suppressive quinacrine was reinstituted on 26 November 1943, 0.4 gram per week, and later increased to 0.6 gram. In November, before suppression was reinstituted, the rate was 3290 per 1000 per annum. In January, after two months on quinacrine, the total rate had dropped to 334 per 1000 per annum. In March the regiment was sent to Emiru, returning in June to New Caledonia.

A reversal of parasite species partition from P. falciparum to P. vivax occurred in this regiment after leaving Guadalcanal and was similar but more marked than that described for the Americal Division.



GRAPH IX. 147TH INFANTRY REGIMENT. MALARIA RATES PER THOUSAND PER ANNUM IN RELATION TO EXPOSURE AND TO THERAPY
Scale differs from Graphs I–VII

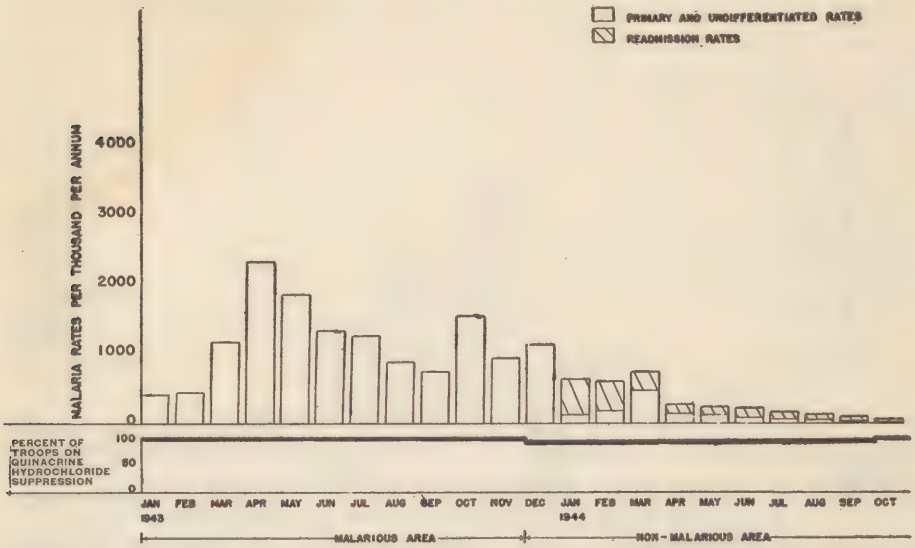
Graph X, 25th Division

This division arrived on Guadalcanal from Hawaii in late December 1942 and took part in the latter part of the campaign for that island. The personnel soon became heavily infected, with a peak rate of 2335 per 1000 per annum in April 1943, despite quinacrine suppressive therapy, 0.4 gram per week, which was not adhered to strictly. The division participated in combat on New Georgia and Vella Lavella from late July to October 1943. In October the rate was 1550 per 1000 per annum. In December the division went to New Zealand and later to New Caledonia. Quinacrine was discontinued in a small control group to determine the amount of seeding. After four weeks, the rate in this group was 2901 per 1000 per annum. Repeated efforts to improve quinacrine administration were associated with a progressive decline in rates to 44 per 1000 per annum in October 1944.

The continuation of suppression in this heavily seeded division during their rehabilitation period in non-malarious areas represented a change in policy from that followed with earlier divisions, the First and Second Marine Divisions, the Americal Division and the 147th Infantry Regiment. The repeated relapses and continued high rates in these divisions in which quinacrine was discontinued clarified the need for continuous suppression if troops were to be rehabilitated promptly for return to combat duty.

Graph XI, 37th Division

This division moved to Guadalcanal in March 1943 and was bivouaced in a relatively well controlled portion of the island, where it instituted an early



Graph X. 25th Infantry Division. Malaria Rates per Thousand per Annum in Relation to Exposure and to Therapy
Scale differs from Graphs I–VII

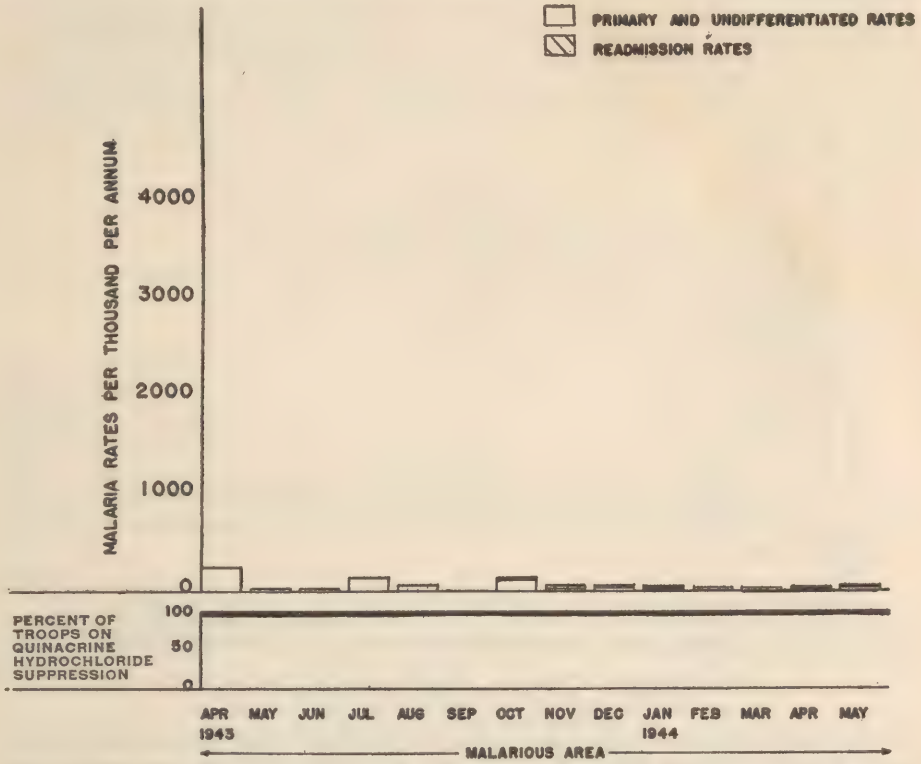
and effective program of larviciding and enforced use of individual anti-malaria protective measures. From late July to September 1943 the division participated in the New Georgia campaign, then returned to Guadalcanal for rehabilitation and restaging. Quinacrine taken by roster 0.4 gram per week was increased to 0.6 gram per week in mid-October 1943. The division was then sent to Bougainville in November 1943 and remained under combat conditions at that base for nearly a year.

Total rates remained low, explained in part by good fortune in having a relatively well controlled area on Guadalcanal at the time epidemic malaria existed there. Credit is due this division for early recognition of the malaria hazard, excellent individual protection, a well supervised program of suppression, and an adequate organization of troop unit anti-malaria details.

A malaria control group was attached to the division in October 1943, the first time that such a group was used for an Army division in the South Pacific theatre.

Graph XII, 43rd Division

This division was moderately heavily seeded with malaria in the Koli Point area of Guadalcanal in February 1943, while enroute to the Russell Islands, and continued in malarious areas on the Russell Islands and New Georgia, through



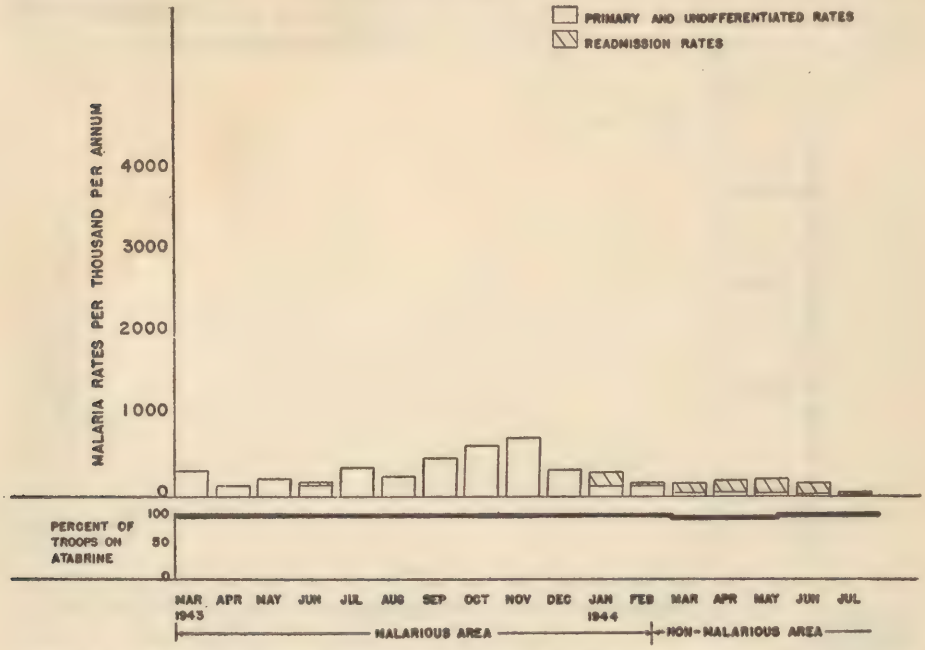
Graph XI. 37th Infantry Division. Malaria Rates per Thousand per Annum in Relation to Exposure and to Therapy
Scale differs from Graphs I–VII

December 1943. During February and March 1944 in New Zealand, where the division had gone for rehabilitation, quinacrine was discontinued in a small control group to determine the amount of seeding. In one company of this group the rate rose to 2025 per 1000 per annum, approximately half the peak rate of the Americal Division. The remainder of the division continued on quinacrine suppressive therapy, 0.6 gram per week, with monthly rates not exceeding 235 per 1000 per annum. By July 1944 the rate was 64 per 1000 per annum. A Malaria Control Group was attached to this division in May 1944.

C. DENGUE FEVER

Epidemics of dengue fever occurred in 1943 on Fiji, New Caledonia, Efate, Espiritu Santo and Tulagi-Florida. The disease was endemic in the local populations. The vectors were domestic mosquitoes which are discussed in Paper III, mainly *Aedes Aegypti.*

Table III shows the uncorrected army rates of this disease for 1943 and 1944 in New Caledonia and Espiritu Santo. In New Caledonia the epidemic of 1943 was localized to the Noumea area but rates were calculated on island strengths.



GRAPH XII. 43RD INFANTRY DIVISION. MALARIA RATES PER THOUSAND PER ANNUM IN RELATION TO EXPOSURE AND TO THERAPY[1]
Scale differs from Graphs I–VII

[1] Total army malaria rates are given for part of the period when the 43rd Division was on the Russells Islands at which time separate rates for this division were not available.

The problem was complicated by the presence of a large civil population. A medieval plumbing system with open drains and inadequate run-off afforded ideal breeding sites. Many cellars contained water thruout the rainy season. Aedes Aegypti larvae were found in flower-pots in the town and cemetery, in laundry tubs and other water containers and in a shipment of rubber tire casings. A house to house inspection and educational program was instituted in cooperation with the French Director of Public Health. Educational material and posters were printed in both French and English.

The 1943 epidemic on Espiritu Santo affected approximately 25 percent of the military population with an estimated loss of 80,000 man days (Paper I).

For several months the eradication of breeding sites of domestic mosquitoes

became more important than anopheline control and occupied a large share of the energy of the base malaria and insect control organization. No cases occurred in 1944 because of adequate mosquito control, even though there were numerous newly arrived and susceptible military populations.

There was no significant outbreak of this disease in 1944 in the military on either Efate or Tulagi-Florida.

D. OTHER INSECT-BORNE DISEASES

Over 70 cases of tsutsugamuchi fever occurred on Bougainville and 3 on Espiritu Santo. About 2,000 cases of filariasis occurred in army personnel, contracted chiefly in the islands of Polynesia. References are given in Paper I.

Great epidemics of enteritis occurred in troops during combat operations on Guadalcanal, Tulagi and Munda, New Georgia. Careful bacteriological studies

TABLE III

*Comparison of 1943 and 1944 dengue epidemics**

Army rates per 1000 per annum

	ESPIRITU SANTO		NEW CALEDONIA	
	1943	1944	1943	1944
January	—	0	0.4	1
February	441	0	65	19
March	1095	0	186	60
April	1713	0	645	54
May	1531	0	317	18
June	909	0	66	12
July	245	0	30	—
August	82	0	3	—

* From Newsletter No. 9 Hq. Malaria and Epidemic Control, South Pacific Area, March 1944 and from Harper et al., Malaria and Epidemic Control South Pacific Area 1942–1944, p. 279b.

were not done. Many observers were impressed with the association between these epidemics and the enormous fly populations which developed in dead bodies, and in exposed feces and garbage. The outbreaks subsided rapidly after the eradication of the fly populations and without any significant change in kitchen or mess sanitation. In a subsequent operation on Okinawa strenuous efforts were successful in preventing the development of significant fly populations. There was only a rare case of enteritis among troops in this latter operation during the first 75 days when combat was severe. No conclusions are drawn from this observation.

E. COMMENT

The epidemiological experiences of military forces in the South Pacific area during the course of three years, involving establishment of many bases in malarious areas, often during combat, are difficult to interpret or to summarize ade-

quately. An immense problem confronted malaria workers on military bases in the New Hebrides and Solomon Islands in late 1942 and early 1943. Malaria was epidemic, trained personnel were few, equipment for control work was inadequate, and stocks of drugs for treatment were low. All efforts were directed to the control of malaria as quickly as possible. The press of immediate control work precluded careful epidemiological studies on the disease, and its vectors. Detailed studies which were conducted later when trained personnel became available are incomplete, since they were undertaken during conditions approximating low grade endemicity rather than epidemic transmission of malaria.

Factors which influenced the malaria rates presented in this paper included amount of malaria resident in the troops, the status of quinacrine suppressive therapy, the extent of the local control problems and the promptness and effectiveness of mosquito control measures. These are discussed in order.

Efate, Espiritu Santo, Guadalcanal, and Tulagi-Florida were in large part originally occupied by previously uninfected troops. In late 1942 and in the first half of 1943, a very great number of troops on Guadalcanal became infected with malaria. This included the 1st and 2nd Marine Divisions, the Americal and 25th Divisions, the 147th Infantry, to a lesser extent the 43rd Division and many personnel of smaller units, Army, Navy and Marine. The 37th Division, on Guadalcanal at this time, did not become heavily seeded, and never showed a high incidence of malaria. These heavily seeded units constituted a large proportion of the personnel who were to occupy bases established at a later date, and markedly influenced the malaria rates on those bases. The presence of heavily seeded troops on bases occupied later in the campaign often made it difficult to determine the degree of local malaria transmission. Occasional organizations arriving directly from non-malarious bases or from the United States furnished a valuable index.

The history of suppression is given in Paper I, and changes in parasite species partition in Paper IV. The dose of 0.4 gram quinacrine per week which was generally given until January 1944 was usually poorly supervised. This dose was insufficient to protect the majority of individuals and even in the conscientious individual often failed to suppress clinical malaria. The weekly suppress sive dose was increased to 0.6 gram per week in January 1944 and malaria ratewere reduced to negligible levels even in heavily seeded organizations, provided supervision was adequate. This must be considered in evaluating the data. The complete discontinuation of quinacrine on many bases and the gradual reduction in the number of troops taking this drug on all bases was associated with a continued fall in malaria rates and was evidence of the effectiveness of mosquito control measures. It cannot be emphasized too strongly that the control of malaria in the South Pacific resulted from the reduction of anopheline mosquito populations because of field control measures on all malarious bases.

Local control problems and the prompt institution of effective anti-mosquito measures were of great importance in influencing the malaria transmission picture. Guadalcanal, with about 110 square miles included within the perimeter, presented malaria control problems of the greatest magnitude because of exten-

sive tracts of low lying marshy ground and numerous land-locked lagoons. Certain of the smaller bases, such as Tulagi, Treasury, Green and Emiru never presented serious technical difficulties. Efate, Santos, the Russell Islands, New Georgia and Bougainville presented problems of intermediate difficulty. Control work other than hand larviciding was delayed for many months after occupation on all of the bases occupied in the first 1½ years of the campaign. Indeed, larviciding was not started on Efate or on Guadalcanal until a malaria epidemic was well under way. Malaria control personnel accompanied or landed shortly after the occupying forces and started control work immediately on the Russell Islands and on all subsequently occupied bases. Even on these bases, however, it was 6 months or more after occupation before semi-permanent control projects requiring heavy equipment were initiated.

It is clear that early insect control measures undertaken by an organization such as that developed in the South Pacific, which is adequately supported and supplied, can prevent malaria and other insect-borne diseases from jeopardizing the success of military campaigns in the tropics. Field control measures directed against disease bearing insects are the basis of any sound program. Suppressive drug therapy and other individual protective action are auxiliary measures of varying value.

F. SUMMARY

Malaria rates of all forces on the major bases in the South Pacific Campaign are presented with brief histories of each base. Similar data are presented for selected army units which proceeded from base to base. A brief account of the dengue epidemics on New Caledonia and Espiritu Santo is given.

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MALARIA AND OTHER INSECT-BORNE DISEASES IN THE SOUTH PACIFIC CAMPAIGN

1942–1945

III. Entomology

P. W. OMAN* and L. D. CHRISTENSON*

The island bases constituting the South Pacific area have been enumerated and discussed elsewhere.[1] The entomological report here presented applies to the 11 malarious bases only unless other islands are specifically indicated, and most of the information given is drawn from observations made on Efate, Espiritu Santo, Guadalcanal, and Bougainville. Whenever possible reference is made to published data used in connection with the preparation of this paper, but we have also drawn freely from unpublished reports prepared by the numerous entomologists who at various times contributed to our knowledge of problems of medical entomology arising from our military occupation of these tropical bases.

Little detailed information regarding the insect fauna of these islands is available, and it is not within the scope of this paper to attempt generalizations as to the origin or affinities of the fauna. However, it is interesting to note that while only 12 species of mosquitoes are known from New Caledonia and 18 from Espiritu Santo, the largest of the New Hebrides group, there are now approximately 70 species known to occur on Guadalcanal in the Solomons group. Prior to occupation by armed forces but approximately 30 species of mosquitoes were known from the entire Solomons. Bougainville, though to date less completely explored, may be expected to have an even richer fauna than does Guadalcanal.

The population of all these malarious bases is predominately Melanesian, excepting Efate and Espiritu Santo where a considerable element of Tonkinese (French Indo-Chinese) occurs. Whites are few. Sanitary conditions, particularly among the Melanesians, are primitive, and the thatched hut dwellings so characteristic of the South Pacific islands offer easy access to mosquitoes and flies (see fig. 1). In addition the Melanesians are confirmed travelers and frequently spend the night along beaches or trails between villages, at which time they undoubtedly serve as a source of infection to mosquitoes in the more isolated regions of the islands. It is small wonder then that malaria is hyperendemic throughout these islands.

Pigs and chickens are common, the former abundant in a wild or semiwild state as well as being domesticated. Horses and cattle, except in the vicinity of plantations, were few, and most of the latter disappeared from the occupied zones

* United States Department of Agriculture; Agricultural Research Administration; Bureau of Entomology and Plant Quarantine.

[1] Malaria and Other Insect-borne Diseases in the South Pacific Campaign, 1942–45. Paper No. 1 of this series: I. General Aspects and Control Measures.

of the Solomons soon after the arrival of large numbers of troops. Dogs were not common and cats were practically unknown until military occupation permitted their increase. One arboreal marsupial, *cuscus* is present and rats and bats are common. There is a great variety of birds, and at least two species of large, tree-climbing lizards in the Solomons. Snakes are not generally common but on Bougainville several species occur in conspicuous populations. Crocodiles occur in the coastal lagoons and small sluggish streams.

FIG. 1. VIEW OF NATIVE VILLAGE, GUADALCANAL, SHOWING TYPICAL THATCH SHELTER CONSTRUCTION

A. TOPOGRAPHY AND CLIMATE

1. Physical features

The general physical features and origins of the islands have been discussed in paper no. 1. Here it is proposed to point out the more important physical features of the occupied zones with particular attention to their bearing on entomological problems encountered.

Efate (New Hebrides).—A relatively small occupied area with few permament streams and no large rivers. The coastal sections are underlaid with coral and with hills extending to the sea. Coconut, coffee, and cacao plantations are common.

Espiritu Santo (New Hebrides).—Occupied area approximately 40 square miles in the southeastern portion of the island, consisting of a long, narrow, coastal strip extending from Turtle Bay on the north to the Renee River area on the south. Numerous large streams and rivers, some of them underground and

emerging from coral craters near the coast. The larger rivers subject to considerable variation in flow, often becoming swollen and rapid in rainy seasons. Upon receding, these rivers leave numerous pools behind sandbars and in catchments along their courses. The banks of smaller streams usually with heavy jungle growth which often overhangs into the water in such a manner as to impede flow or form lodgment for aquatic growth. Coastal sections underlaid with coral and with hills extending to or near the sea. South of the Renee River numerous ponds occur. Coconut, coffee, and cacao plantations are common. Soil sandy near the coast but quickly giving way to a fine textured, relatively impervious clay. Swamps few in number and these usually limited in extent. Areas not cultivated are covered by a dense rain forest. Numerous smaller islands off shore, some of which were occupied by troops. On some of these small islands *Anopheles* were never found during the course of military occupation and malaria was not a problem.

Guadalcanal (Solomon Islands).—The occupied area consisted of approximately 110 square miles along the northwest coast and included approximately 45 miles of coast line. This area, east of the Lunga River, consisted of a broad alluvial plain varying in width from one to 10 miles, transected at intervals of approximately 3 miles by major drainage courses arising in the high elevations to the south. Between these rivers (Lunga, Teneru, Nalimbu, Metapona, and Balasuna) are numerous sluggish, meandering streams representing old river beds in the process of being resedimented. Most drainage courses in this area, both rivers and small streams, are bordered by heavy jungle; between these jungle areas are broad open grasslands extending back into the foothills. Beaches in this section are composed of dark volcanic sand. Soil, except for beach strip, consisting of fine black silt, high in organic content, overlaying a yellow clay subsoil. The topsoil, when undisturbed, was capable of absorbing an enormous amount of water, but once rutted and packed by vehicular traffic became highly impervious. West of the Lunga River valley the hills approach or reach the sea, the permanent streams are fewer and smaller, and many of the secondary drainage courses are dry except during periods of abundant rain. The soil is underlaid with coral and for the most part sandy and coarser than in the eastern portion of the occupied zone. All small streams are periodically blocked at the mouth by a high, pounding surf, forming lagoons of fresh or brackish water. These lagoons sometimes remained blocked for a sufficient length of time to spread into the adjacent low areas and form coastal fresh water swamps. Adjacent to the foothills are numerous fresh water swamps, some jungle covered, others with a heavy covering of emergent aquatic or semiaquatic vegetation. Oxbows are common along the large streams in the broad alluvial plain east of the Lunga. Coconut plantations are common west of the Teneru River.

Tulagi-Florida Group (Solomon Islands).—The occupied area was small. The numerous small islands are without major drainage courses and with little permanent water. Hills extend to the sea and the coastal section is underlaid with coral. Coconut plantations are common. All entomological work was by Navy personnel.

Russell Islands.—The occupied area was small. The small, low islands are without major drainage courses and have little permanent water. Hills extend to the sea and the coastal section is underlaid with coral. Coconut plantations are common. Entomological work was entirely by Navy personnel.

New Georgia (Solomon Islands).—Approximately 20 square miles of occupied area in which the thin layer of soil is underlaid with coral. There are no large streams and few small ones. A few swamps were present in or adjacent to the occupied area but these were not utilized by *Anopheles farauti* as they were deeply shaded.

Bougainville (Solomon Islands).—The Bougainville perimeter was first stabilized to include an area of 30 square miles and later expanded to 50 square miles. The soil differs from that on other bases in that it is essentially volcanic sand for some miles inland. The terrain consists largely of a series of sandy terraces transected by a few streams and rivers, some of which were clogged by the debris of centuries with the result that each sandy terrace contained a series of swamps. A high water table, which quickly filled "fox holes" and shell or bomb craters, characterized many areas. The eastern portion of the occupied area consists of foothills, often steep, which lie at the base of high mountains and an active volcano. As on Guadalcanal, streams periodically blocked at the mouth by sand bars thrown up by a high, pounding surf, forming lagoons and coastal swamps. No extensive plantation areas. Jungle with dense undergrowth. Subsoil drainage good.

Green Island.—Coral atolls with only a thin layer of soil, a few coconut plantations, and some jungle. There was a limited insect fauna and no major control problems. Entomological work on Green Island was entirely by Navy personnel.

Treasury and Emiru Islands.—Primarily coral with a thin topsoil, without large streams and with but a few swamps which were easily drained to the sea. The insect fauna limited and not involving major control problems.

Vella Lavella.—The occupied area was a narrow coastal strip where the soil was underlain with coral. Hills came almost to the sea. The area was transected at frequent intervals by small streams and contained a few swamps which were easily drained to the sea once adequate equipment was available.

2. Climatological

Available climatological data are given in paper no. 1. On Guadalcanal rainfall for 1944 totaled 87.74 inches at the Henderson Field weather station and 81.69 inches at Carney Field. Complete data are not available for Doma Cove at the western end of the occupied zone but the total rainfall was approximately that recorded for Carney Field. February was the month of heaviest precipitation at all stations, and more than 8 inches of rainfall was recorded at all stations on each of the first 4 months of the year. The distinction between the wet and dry seasons was not marked, and at Henderson Field the rainfall was above the recorded 25-year average for each month except January, November, and December. The daily temperature range was approximately 20°F., the maximum sel-

dom being above 92°F., or the minimum seldom below 69°F. The average relative humidity was seldom below 80 for any month.

These data for Guadalcanal are fairly representative of all the major bases. However, the distinction between wet and dry seasons was more pronounced in the New Hebrides and less evident on Bougainville. The total rainfall on Bougainville was considerably higher than on Guadalcanal. It is emphasized that the "dry season" and "wet season" are relative terms. During most months of the year there was sufficient rainfall to maintain surface water in all except the smallest catchments, and the abundant rainfall and relatively high temperatures and humidities provided conditions ideal for the development of large mosquito populations.

Seasonal changes in the entomological problems, particularly with respect to mosquitoes, were influenced largely by rainfall. Following the onset of heavy rains at the beginning of the wet season, floodwater *Aedes* would become abundant and at times troublesome. Flooding of normal breeding areas of such forms as *Culex* and *Anopheles*, so that the available water surface was increased many times, served to disperse the current larval population and this gave the impression that there was a cessation of breeding. To some extent this was probably true, since torrential rains caused flushing of some surface pools and larval development, in exposed situations, was probably inhibited by the constant or frequent agitation of the water surface and the lowering of the water temperature. Periods of heavy rainfall, with the consequent flushing of drainage courses, resulted in temporary elimination of breeding in most rivers and streams.

On most bases, the peak of *Anopheles* population curves usually occurred soon after the end of the season of heavy rains. A number of factors apparently contributed to this situation. The stabilization of abundant surface water, increased sunlight and its resultant effect on development of plant life, and higher water temperatures, combined to make conditions ideal for larval development. Larvicidal crews were sometimes temporarily overwhelmed with work and unable to reach the more inaccessible breeding areas. This situation could usually be corrected in a short time, the speed with which it could be accomplished being dependent upon the progressive drying up of pools and the gradual improvement in larvicidal coverage.

The advent of the dry season usually meant an abrupt dropping off of the abundant populations of flood-water *Aedes* except in coastal jungle areas where diminished populations frequently persisted throughout the year. As sunlit surface pools decreased in size they frequently became unsuitable for *Anopheles* development and *Culex annulirostris* would be the only species of mosquito to utilize such places. On bases characterized by a fairly evenly distributed rainfall such as Bougainville, *Anopheles* and other mosquitoes were generally abundant at all times unless control measures were instituted. On Bougainville increase of *Anopheles* populations was most rapid during the frequent prolonged periods of light afternoon showers which served to keep all water catchments filled without subjecting them to flushing action.

B. ENTOMOLOGICAL PROBLEMS ENCOUNTERED

1. Malaria Vectors

Anopheles (*Myzomyia*) *farauti* Laveran was by far the most important and probably the only important malaria vector in the South Pacific area, at least from a military standpoint. Other species of *Anopheles* encountered, namely *punctulatus* (S. & S.), *lungae* B. & S., *koliensis* Owen, *solomonis* B., K. & R., and *nataliae* Belkin, while on occasion abundant in restricted habitats were seldom present in sufficient numbers to be considered major factors in malaria transmission. Of these species, *koliensis* is strongly anthropophilic and thus potentially an important vector, *punctulatus* feeds freely on man in captivity but apparently only rarely in nature, while the remaining species are apparently largely dependent upon native wild hosts for blood meals. Details of available information concerning these species may be obtained from published articles.[2]

In addition to being an exceedingly efficient vector, *A. farauti* exhibits adaptability to a great range of habitats for larval development. Although the highest concentrations of larvae were usually found in sunny, slightly brackish lagoons in association with emergent vegetation or flotage, the species effectively utilizes almost every conceivable type of aquatic habitat with the exception of artificial containers, tree holes, open moving water and highly saline water. In the course of investigations in the South Pacific Area, larvae were found in temporary water catchments of many kinds, in streams, rivers, ponds, seepage areas, open wells, and both fresh and tidal swamps and lagoons. Prior to occupation of an area by troops, larval populations appeared to be largely restricted to lagoons, streams, and rivers. Following occupation and the consequent creation of innumerable road ruts, "fox holes," borrow pits, and road ditches, *farauti* quickly utilized all these places and in the absence of control operations developed enormous populations. *Farauti* does not commonly occur in heavily shaded areas, and its occurrence in swamps is usually restricted to the more open sections.

Both *koliensis* and *punctulatus* are found in typical *farauti* habitats in the larval stages, especially during the wet season, although *punctulatus* apparently disappears from the coastal section of Guadalcanal during the dry season. *Lungae* occurs in coastal swamps and seepage area, and shows a decided preference for shaded habitats. *Solomonis* and *nataliae* both occur in the low foothills section along the northwest coast of Guadalcanal, the former being collected from pot

[2] Belkin, John N., *Anopheles nataliae*, a new species from Guadalcanal. Jour. Parasitol., **31**(5): 315–318, 1945.

Belkin, John N., Knight, Kenneth L., and Rozeboom, Lloyd E., Anopheline mosquitoes of the Solomon Islands and the New Hebrides. Jour. Parasitol., **31**(4): 241–265, 1945

Belkin, John N., and Schlosser, Ralph J., A new species of Anopheles from the Solomon Islands. Wash. Acad. Sci. Jour., **34**(8): 268–273, 1944.

Daggy, Richard H., The biology and seasonal cycle of *Anopheles farauti* on Espiritu Santo, New Hebrides. Ent. Soc. Amer. Ann., **38:** 1–13, 1945.

Owen, William B., A new anopheline from the Solomon Islands with notes on its biology. Jour. Parasitol., **31**(4): 236–240, 1945.

Perry, William J., Keys to the larval and adult mosquitoes of Espiritu Santo (New Hebrides) with notes on their bionomics. Pan-Pacific Ent., **22:** 9–18, 1946.

holes in a coral stream bed and from seepage areas, usually in clear water, deeply shaded, while the latter was taken from densely shaded, clear running water in seepage or spring areas. *Koliensis* has been found only in the alluvial plain area east of the Nalimbu River on Guadalcanal.

Females of *farauti* and other species of *Anopheles* encountered are primarily nocturnal in their blood-feeding habits, although daytime biting by *farauti* under favorable conditions was not uncommon. Following blood meals the females frequently remain in darkened portions of native huts or closed tents throughout the following day but in open tents such as were used by troops there was little evidence that the mosquitoes lingered after feeding. The diurnal resting places of *farauti* apparently consist of any cool, moist, shaded places. With the exception of blooded females no large concentrations of adults in diurnal resting places were encountered.

There is considerable evidence to indicate the existence of at least two races or physiological strains of *farauti* on Guadalcanal. It was repeatedly observed that adult females reared in large numbers from larvae collected outside the zone of normal human habitation would not feed readily on humans in captivity. Attempts to collect adults at night in such areas, even where larval populations were extremely high, invariably resulted in almost complete failure. On the other hand insectary colonies established from eggs obtained from blooded females collected in native huts, or from larvae collected in the vicinity of human habitations, usually produced females that fed readily in captivity. While inconclusive, such evidence strongly indicates that these "wild" populations are maintained by blood meals taken from birds, pigs, or other wild animals. Host preference tests conducted on Efate indicated that *farauti* would feed readily on cattle, horses, goats, pigs, dogs, and chicken, and that both cattle and horses are preferred to man for the blood meal.

These remarks are not intended to imply that these physiological strains, if they do exist, are fixed in their food habits. On the contrary it is believed that these "wild" strains could and did adapt themselves readily to humans whenever the opportunity offered. For this reason, in recommending control operations, no distinction was made between presumed "domestic" strains and those believed to be "wild."

In considering control operations in the South Pacific Area, it should be remembered that they were initiated and developed on most bases before DDT with its enormous labor-saving potentialities became available or even known. Two alternatives were thus available: either an extensive, never-ending, and sometimes an all but impossible larvicidal program, or a planned elimination of breeding places. In actual practice both alternatives were of necessity followed. A larvicidal program was begun at the earliest possible time, and as equipment and labor became available semipermanent control projects were undertaken. On most bases planned elimination of breeding places was never sufficiently effective to obviate the necessity of a thorough larvicidal program. Elimination of breeding places was of great importance however, since it served to bring the total

water surface within the capacities of available larvicidal crews and at the same time contributed greatly to the overall reduction of mosquito populations. It was the entomological survey group's responsibility to determine the projects to be undertaken and to participate in determination of work priorities.

Since larval populations in permanent water courses are usually associated with vegetation, a program of stream cleaning was recommended. This accomplished the desired result in three ways: it eliminated protective vegetation, it made the remaining breeding foci accessible to larvicidal crews, and it insured swifter flow of water with consequent flushing action in the streams following

FIG. 2. A SLUGGISH STREAM IN NEED OF RE-CLEANING
In streams with sufficient fall flushing dams would effectively prevent formation of algal mats and to some extent the regrowth of marginal vegetation. Photo No. 44-4796, 161 Photographic Company.

rains. Frequent recleaning was necessary (see fig. 2). In stream courses with sufficient fall, flushing dams were recommended. These proved effective.

Control of *Anopheles* in lagoons depended to a considerable extent upon the elimination of vegetation and flotage. This could usually be accomplished by periodic opening of the lagoon to the sea to permit drainage or tidal action and salinification. Where barrel-type flumes were installed and properly maintained they proved to be one of the most effective and economical of the control methods. It was first believed that the increased salt content of the water was responsible for cessation of *farauti* breeding, but this factor alone was found not responsible except as it contributed to the elimination or change of vegetation. Careful

tests of the saline content of the water in many lagoons so treated showed that in no instance was the salinity of the water above the known tolerance for *farauti* larval development. In addition to the flushing action created by the installation of flumes there was also a great reduction in water surface.

By far the greatest source of widespread breeding of *A. farauti* was in the innumerable man-made catchments, in which at times, it is estimated that 90 per cent of the breeding occurred. The most important of these were ruts, improperly constructed ditches, and abandoned "fox holes." Coconut, coffee, and cacao groves, with their excellent camouflage, were widely used for supply dumps

FIG. 3. ANOPHELINE BREEDING SITES ON BOUGAINVILLE CREATED BY AN ARTILLERY BARRAGE
Photograph by Major John Weir

of all kinds with the result that miles of ruts were cut as vehicles traveled up and down row after row of trees. Thinned jungle areas used for supply dumps, and the omnipresent logging operations created extensive rutted areas in a similar manner. On Guadalcanal the extensive grasslands which permitted indiscriminate movement of vehicular traffic proved to be a serious and long continuing problem. Eventual elimination of rutted areas was accomplished by thorough discing, associated with proper ditching and road construction.

Shelling and bombing in combat areas proved to be only minor factors in the creation of *Anopheles* breeding sites. On Bougainville, however, a concentrated air and artillery barrage of enemy positions later occupied by our troops presented serious local problems which were quickly abated by filling operations (see fig. 3).

2. Dengue Vectors

But one certain vector of dengue fever, *Aedes* (*Stegomyia*) *aegypti* (L.), the yellow fever mosquito, occurs commonly in the South Pacific area. In habits primarily a domestic species, it was apparently responsible for severe outbreaks of dengue on New Caldeonia, Efate, Espiritu Santo, and Tulagi-Florida in 1943 and for a mild outbreak on New Caledonia in 1944. Until November 1943, when a localized infestation of *aegypti* was found on Guadalcanal, the species was not known to occur in the occupied portion of that base. Critical survey work to determine the limits of this infestation, followed by a diligent clean-up program, resulted in the elimination of this infestation by midyear in 1944. There is no reason to believe that any cases of dengue resulted from this temporary infestation of *aegypti* on Guadalcanal.

There is considerable reason to believe that *Aedes* of the *scutellaris* complex may at times be involved in the transmission of dengue. Daggy[3] has reported on a dengue epidemic on Espiritu Santo in which a member of the *scutellaris* complex, *hebrideus* Edw., appeared to be an important factor. There is need for considerable critical work in order properly to evaluate the role of various species of *Aedes* as vectors of dengue fever.

Aegypti is commonly found only in the immediate vicinity of human habitation, where it breeds in almost any kind of artificial container. In the New Hebrides and Guadalcanal, under conditions of early military occupation, it found abundant favorable conditions for development in truck tires piled in supply and salvage dumps. In New Caledonia, where there is a concentrated civilian population, the chief source of breeding was in water containers around dwellings and in the numerous flower vases in cemeteries. Although not so completely domestic, the members of the *scutellaris* complex breed in most situations that are suitable for *aegypti* but also utilize a great many types of situations such as tree holes, coconut husks, and the like. The thoroughness of the control program, primarily one of survey inspection and elimination of breeding places, was directly responsible for reducing or preventing dengue outbreaks after the severe epidemics of 1943.

3. Filaria Vectors

Filariasis is common among the Melanesians in the South Pacific, but was not a problem of military importance except in the Polynesian islands, where the vector is culicine, *Aedes* (*Stegomyia*) *pseudoscutellaris* (Theo.). A summary of the relation of the *scutellaris* group of *Aedes* to filariasis is given by Farner and Bohart.[4] Little was known concerning the vector of filariasis in the New Hebrides and Solomons at the time of occupation of those bases, but subsequent investigations indicate that the disease was transmitted largely by *Anopheles*, particularly *farauti*, although *koliensis* appears abundantly capable as a vector. Although a number of species of mosquitoes are capable of picking up the micro-

[3] Daggy, Richard H., War Med., **5**: 292, 1944.

[4] Farner, Donald S., and Bohart, Richard M., Naval Med. Bul., **44**(1) : 51, 1945.

filaria, few harbor the worms to the infective stage. Available data in unpublished reports are based upon dissection of collected material and upon dissection of specimens fed on known infected Melanesians.

Because the vectors of filariasis were those of primary concern from the standpoint of malaria transmission, in the Solomons and New Hebrides the control of filariasis was solved with the reduction of *Anopheles* brought about by malaria control activities.

4. Pest Mosquitoes

Aside from their importance as vectors of disease, mosquitoes were frequently of considerable importance in restricted areas because of their annoyance. This applied to both combat and rear area troops. No measure or even accurate estimate of the importance of this annoyance in the prosecution of the war is possible, but it must be recognized as considerable purely from the standpoint of lessened efficiency. In addition, it was probably at times a contributory factor in a general lowering of morale, psychoneurosis, and even loss by enemy action. On the other hand, the presence of pest mosquitoes, whenever they occurred in numbers, probably greatly increased the extent of observance of individual protective measures and was therefore of some influence in reduction of malaria incidence. Among the species of mosquitoes that assumed importance purely from a pest standpoint are:

Aedes (*Ochlerotatus*) *vigilax* Skuse.—This species, breeding in the salt and brackish marshes of New Caledonia, was blown or drifted in countless numbers into the inland valleys of that base. As a result, sections that would have been ideal for hospital sites and rest areas were at times thoroughly plagued by a fierce and persistent daytime biter. Under such circumstances outdoor activities, particularly swimming, became an ordeal rather than a relaxation. To some extent these populations could be reduced by airplane spraying with DDT, but observations following such area treatment indicate that the effect was extremely transitory and that adult populations were back to normal after about one week. Claims of nearly complete elimination of the adult population, and a lag of two to three weeks in reinfestation of an area are apparently without basis.

Aedes (*Aedes*) *funereus* (Theob.), *A.* (*A.*) *ornatus* (Theob.), *A.* (*Aedimorphus*) *vexans* Meigen, and *A. imprimens* (Walk.), all floodwater species, were at times abundant and extremely annoying in jungle or coconut-grove sections on the bases where they occurred. They are fierce and persistent daytime biters, but like most *Aedes* have a short flight range and were not troublesome far from breeding areas. Most instances of annoyance in camp areas could be traced to local water catchments. Except for the deeper jungle areas these species largely disappeared during the dry season.

Aedes (*Stegomyia*) *hebrideus* Edw. and *A. quasiscutellaris* F. & B. breed in tree holes, coconut shells, tin cans, and artificial water catchments of all kinds. They are apt to be the most abundant daytime biters and are very persistent and annoying. Normal clean-up measures such as are directed against *aegypti* will usually suffice to reduce the population to a negligible point.

Culex annulirostris Skuse.—This is by far the commonest mosquito in the New Hebrides and Solomon Islands where it breeds in enormous numbers in all kinds of natural water catchments. It will utilize pools long after they are unsuitable for *Anopheles* development. It is primarily a night biter and was consistently taken in night population samples when other species of mosquitoes were extremely scarce. It does not commonly occur in deep jungle areas, seeming to prefer the more open coconut groves and thinned jungle areas that were so extensively used for bivouac sites.

5. Flies

With relatively few exceptions flies were of little consequence in the South Pacific area, but when abundant, or permitted to become so, were believed to be important in connection with dysentery outbreaks, in addition to being extremely annoying. On Efate and Espiritu Santo, early in 1943, two species, *Musca sorbens* Wd. and an undetermined species, were present in great numbers, and clinical evidence suggested that these flies were in large part responsible for outbreaks of bacillary dysentery. In addition to their presence in mess halls and latrines these flies were constantly present during daylight hours outdoors. They were extremely persistent in their attempts to feed on any open sore or wound, and if given the slightest opportunity would fly into the mouth, nostrils, eyes, or ears. Normal sanitary measures and the removal of cattle from adjacent groves where they were customarily permitted to graze usually sufficed effectively to curtail these *Musca* populations.

In the Solomons, and to some extent the New Hebrides, *Chrysomya megacephala* (F.) was extremely abundant in and around garbage pits, trash dumps, and latrines. It did not habitually frequent mess halls. Normal sanitary measures would control this species.

On Guadalcanal, *Hermetia illucens* (L.) was sufficiently common in latrines to earn the name "latrine fly." It was chiefly of annoyance and so far as known has no importance in connection with disease transmission.

Sand flies, *Acanthoconops albiventris* (Meij.), were abundant and troublesome on some beach areas on Guadalcanal. They were restricted to sandy beaches and usually to sections within a quarter mile of a beach lagoon. Investigations indicate that optimum conditions for larval development occur only in a relatively narrow strip of beach near the high tide line, and the greatest concentrations of larvae appear to be just inside the mouth of lagoons where the sandy beach grades into the finer silt and muck. No larvae were found, their occurrence being indicated by adult emergences. *Acanthoconops* bites freely during the daytime. The bite is not painful but causes rather severe reactions in some individuals. The species was chiefly of concern as an annoyance in recreation areas and is not known to transmit any disease on Guadalcanal. Temporary reductions of adult sand-fly populations were obtained by area treatment with DDT oil solution and with DDT thermal generator applications. Sand flies were also abundant and troublesome in troop recreation areas along beaches, and in combat beach areas on Bougainville.

6. Other Arthropods of Importance

Scrub typhus, transmitted by trombiculid mites (chigger mites), was encountered in the South Pacific on Espiritu Santo, Munda (New Georgia group), and Bougainville, but only on the last-named base was there evidence of any considerable reservoir of the disease. Individual protective measures, particularly avoidance of likely mite habitats and use of dimethly phthalate on skin and clothing appeared to offer the best insurance against contracting the disease. Information as to the efficacy of cutting and burning vegetation thought to harbor the mites and their larval hosts is not conclusive.

Ants (species unknown) were abundant everywhere in the New Hebrides and Solomons. They were of importance only as a nuisance, being attracted to any available sweet or oily delicacies such as candy, cookies, and peanuts. Occasionally they established nests in clothing or other impedimenta left undisturbed for a few days. DDT, applied to screens and around the floor of quarters was highly effective against ants and virtually eliminated them as pests.

On Bougainville, and to a lesser extent on some other bases, an unusually large centipede common throughout the occupied area was the cause of much annoyance. The bite was exceedingly painful and was often followed by reactions so severe as to require hospitalization.

C. ORGANIZATION OF SURVEY ACTIVITIES

A personnel organization for entomological survey activities that proved adequate for the average area assignment follows:

DESIGNATION	NUMBER	DUTIES
Entomologist	1	Officer (Army SnC or Navy H-V(S)) in charge
Senior NCO	1	Direct supervision of field and laboratory work
Laboratory and insectary men	2–3	Map making, record keeping, care and identification of material brought to or reared in insectary
Field men	5–8	Responsible for field surveys and reports of field conditions

The entomologist and his crew were responsible for, (a) surveys to determine the incidence, distribution, and biology of arthropods of medical importance, (b) recommendations as to the areas requiring control operations, the relative importance of these areas, and their proper treatment, (c) routine inspection surveys to determine the effectiveness of control measures, (d) maintenance of appropriate maps and records of insect populations and their fluctuations in response to control activities or other factors, (e) special investigations of immediate importance to control operations or to the health and welfare of troops, and (f) participation in the general training program.

It is emphasized that the personnel organization, and the responsibilities of the survey group, were plastic arrangements in actual practice, subject to change from day to day as conditions and problems encountered in the different areas varied.

Although constantly alert for any problems in medical entomology, primary

attention was nearly always directed toward the major problem, malaria. Consequently, the entire survey organization was planned to furnish information on mosquito populations and their control. Other activities were of a secondary nature. The entomologist necessarily devoted a great deal of time to field work, especially during the early stages of occupation of an area. It was necessary for him to be familiar with the entire assigned territory in order to interpret survey data intelligently, to recognize the types of problems to be expected, and to anticipate laxity on the part of the field crews. Frequent discussion of problems with the survey crew was encouraged and with inexperienced personnel this often involved interviews twice daily.

Field work by the survey team was usually assigned on the basis of sub-areas of from three to five square miles per individual or team. If two or more individuals worked together as a team the senior in rank was made responsible; if subareas were assigned to individuals there was individual responsibility under the direction of a designated field supervisor who worked in any or all subareas as the need arose. On some bases the entire survey crew worked throughout all assigned territory. This system had the advantage of not concentrating the work of the less efficient survey men in a single subarea or subareas, and of giving all portions of the territory the benefit of the work and observations of the most efficient survey men.

Whatever arrangement of personnel assignment was used, the survey crew was expected to cover its territory once each checking period so that a complete and continuous record of mosquito populations was available. Both weekly and fortnightly checking periods were used at different times and on different bases. Survey personnel were expected to furnish information not only on insect populations but also on the status of control projects, the location of potential hazards such as unauthorized can and garbage dumps, on the occurrence of new problems, and to make recommendations for the correction of problems encountered. As such items became available survey personnel also carried small hand sprayers for larviciding small water bodies found to need treatment.

Survey men assigned to laboratory and insectary work were charged with the responsibility of rearing specimens, identification of specimens caught in night catches, preparation of record maps at the end of each checking period, maintaining records of adult catches, assisting in experimental work, and helping with the usual office and laboratory routine. In addition, they were expected to spend some time in the field, either with members of the field crew or in independent survey activities.

In addition to the survey unit organization discussed above, on some of the larger bases such as Espiritu Santo, Guadalcanal, and Bougainville there was need for central coordination of entomological activities. To accomplish this end there was designated for each of these bases an "island entomologist" whose duties were to plan, coordinate, and supervise the general survey program and to advise the island malariologist concerning the broader aspects of the entomological work. This was not a command position, and the extent to which the desired cooperation was actually attained was to a considerable degree dependent upon

the extent to which the program could be sold to the island malariologist and the participating entomologists. In some respects the results were good, but experience indicates a very definite need for supervision of entomological work by an entomologist in whom is vested authority as well as responsibility.

The very nature and multiplicity of duties assigned to the entomologist and his crew usually made it impossible for him to carry out adequate investigations of all problems encountered. Whenever possible, essential investigations were carried out in cooperation with research units such as Naval Medical Research Unit No. 2, which sent advance parties to the South Pacific area. On some bases, a cooperative program of investigational work was developed under the direction of the island entomologist. As they arose, special problems were assigned by the island entomologist. Such problems included methods of application of DDT, toxicity of DDT, tests of repellents, surveys of special territories, and special studies of insect biologies.

On Guadalcanal and elsewhere meetings of all district and division entomologists were held monthly, or more often if considered desirable. These meetings were initiated by the island entomologist primarily for the purpose of discussing and clarifying administrative procedure. Once this phase of the entomological work was established the meetings were continued in order to permit an interchange of ideas and a general discussion of practical problems encountered. These meetings did much to further the coordination of entomological activities and aided materially in the development of a comprehensive investigational program designed to supply information of direct benefit to control activities. In addition there were developed standardized methods of larval population sampling and uniform methods of reporting, so that reports from various districts could be readily consolidated and compared.

Occasionally entomologists or other survey personnel were charged with functions quite distinct from normal survey activities. Among these were: (a) Development of a mobile unit to service aircraft used in aerial application of DDT, and working out an operational procedure for same. (b) Scheduling and supervising airplane spraying of DDT, including the activities of the ground service unit, and (c) participation in mosquito control programs, either by being made directly responsible for the larviciding phases, or through periodic assignment of survey men to larvicidal crews.

D. SURVEY DUTIES AND PROCEDURE

1. Initial Surveys

Ideally, the initial survey of a territory followed a critical study of maps and aerial photographs of the area. However, in actual practice, at least in the early phases of the South Pacific campaign, this was seldom possible because of the inability to obtain satisfactory maps or photographs. The original survey work was thus to a considerable extent exploratory in nature and designed to give a general picture of the physical features of the terrain and the problems involved. As the survey progressed, and at least within a few days, it was expected to

furnish preliminary information on the following: (a) location, extent, and description of actual or potential mosquito breeding places. (b) Records of larval populations. (c) Records of current adult populations. (d) Location of native villages, or other reservoirs of infection of tropical diseases and (e) conditions considered actual or potential hazards from the standpoint of insect borne diseases.

Control operations, particularly mosquito larviciding, were begun concurrently with survey work under most conditions. The initial surveys, while admittedly sketchy and incomplete in character, nevertheless directed attention from the outset to the most important and urgent problems existing in the area under consideration. As survey work progressed it was translated into specific recommendations for a control program, usually drawn up in conjunction with the sanitary engineer assigned to the district. An example of such a set of control projects developed on Guadalcanal and prepared by the entomologist of the district concerned is quoted:

HEADQUARTERS
MALARIA & EPIDEMIC CONTROL
APO 709

9 February 1944

Subject: Malaria and Epidemic Control Projects in the Teneru Area.
To: Malariologist, Teneru Unit, APO #709.

1. Projects for which the Island Malaria Control Organization is directly responsible.
   A. Heavy equipment or dynamite work.
      1. Ditch area west of 716 Medical Sanitary Company in vicinity of (95.5–91.5) into Little Teneru River with sufficient laterals to drain entire area. Work now in progress. Work estimate, dragline for 10 days.
      2. Extend ditching of upper Ellis, Chappel, and Parks Creeks, with sufficient laterals, to drain area in vicinity of (100.0–90.5). Work estimate, dragline for 14 days.
      3. Drain area in vicinity of (101.8–89.4) possibly by ditch to Nalimbu River along telephone line. Work estimate, dragline for 14 days.
      4. Ditch low area at west end of Nalimbu River bridge into Nalimbu River. Work estimate, bulldozer, leaning wheel grader, and hand ditching crew for 1 day.
      5. Drain oxbow at (104.0–94.0) into Nalimbu River. Work estimate, dragline and bulldozer for 4 days.
      6. Drain area in vicinity of (104.0–97.5) into Herr Creek or Cranford Creek. Work estimate, dragline and bulldozer for 3 days.
      7. Fill or drain into Yankee Creek numerous potholes along lower Yankee Creek in vicinity of (102.8–96.6). Work estimate, bulldozer, dynamite crew and hand filling and ditching crew for 7 days.
      8. Channel old creek bed at (104.6–98.2) and connect with Knapp Creek. Work estimate, dynamite crew for 2 days.
      9. Fill potholes along Scott Creek. Work estimate, bulldozer and/or hand filling crew for 4 days.
      10. Drain grassland in vicinity of (102.5–92.5) into ditch of highway 26 *after* ditching high 26. Work estimate, bulldozer and pull grader and hand ditching crew for 7 days.
      11. Drain swamps near old 46 NCB rifle range on Lunga River at (86.3–90.4). Work estimate, dragline and bulldozer for 10 days.

12. Drain area adjacent to Fighter I into upper Ilu River. Work estimate, dragline and bulldozer for 14 days.
13. Drain area between 20th Sta. Hosp. and radio station, vicinity of (90.0–91.0) into Teneru River. Work estimate, dragline and bulldozer for 4 days.
14. Ditch area southwest of Mica Engineers, vicinity of (88.5–95.5), and connect drainage of area with Aviator Creek. Work estimate, dragline or bullodozer and pull grader for 5 days.
15. Drain area south of 21st Medical Supply in vicinity of (93.7–92.5) into Little Teneru River. Work estimate, dragline for 3 days.
16. Clear logs and old bridge from Little Teneru River at (93.7–91.5) and from (93.5–91.2) to southern extremity of controlled area. Work estimate, caterpillar and crew for 14 days.
17. Services of level crew prior to initiation of all drainage projects are assumed. Work estimates do not cover time required by this crew.

B. Hand cleaning by native crews.
1. Tributary to Parks Creek at (101.2–92). Work estimate, 50 man days.
2. Herr Creek, especially upper end. Work estimate, 150 man days.
3. Slough paralleling road to 13th A.F. at (104.1–96.0). Work estimate, 250 man days.
4. Oxbow at (104.0–94.0). Work estimate, 1000 man days.
5. Scott Creek. Work estimate, 200 man days.
6. Mouth of Hook Lagoon. Work estimate, 50 man days.
7. Upper Ilu River at (89.5–93.1). Work estimate, 200 man days.
8. Tributary to upper Ilu River at (91.0–93.7). Work estimate, 200 man days.
9. Ditch adjacent to Lunga River and highway 26 at (83.6–93.6). Work estimate, 100 man days.
10. Maintenance work on streams. Work estimate, standing crew of 50 natives.

C. Elimination of road ruts, puddles, fox holes, etc. in areas outside of bivouac sites. Work of this type may involve use of disk harrow, bulldozer, or hand crew. Principal territories where such work is needed are:
1. Road ruts at edge of grassland from vicinity of sawmill at (99.2–89.2) to the east.
2. Fox holes on each side of highway 26 near Nalimbu River, vicinity of (104.0–90.5) and (104.5–91.4).
3. Road ruts in grassland in vicinity of upper Oman Creek.
4. Road ruts and small irregularities in the area west of 716 Medical Sanitary Company now being ditched.
5. Fill well near Herr Creek at (104.0–98.0).
6. Road ruts around Kiwi and Radar station in vicinity of (100.7–96.4).
7. Road ruts between Hook Lagoon and Nalimbu River in vicinity of (105.5–99.5).
8. Fill oxbow near mouth of Dodo River at (96.1–94.9).
9. Road ruts throughout grasslands between Little Teneru River and White Creek.
10. Road ruts in grassland south of 20th Station Hospital.

2. Projects of a public works nature falling for the most part under the general supervision of the Forward Area Engineer.

A. Road ditches. The principal deficiencies in the present drainage system are those resulting from improper road construction and ditching. In order to insure ready run-off of surface water from the extensive grasslands in this area it is essential that road ditches, particularly those along the main roads, be cut to grade and the ditch system integrated with the natural drainage system. Further, it is essential that adequate and properly placed culverts be incorporated into this ditch system. Outstanding examples of deficiencies in road ditching are:
1. Highway 26 between Nalimbu River and Dodo River and between Ilu and Lunga Rivers.

2. Road north of highway 26 past 13th A.F. to the beach.
3. Road to 37th Division combat range for 1½ miles south of highway 26.
4. Road from highway 26 to directional radio station at (100.8–91.1) and beyond to sawmill.
5. Road from highway 26 past 20th Sta. Hosp. to radio station.
6. Road between Henderson Field and Fighter I.

B. Road Net. It is highly desirable that the agency responsible for the planning of a road net indicate where additional graded roads are needed so that such roads can be established and non-essential roads closed. Many bivouac areas are not now accessible by graded roads, hence vehicles drive through grasslands and continue to cut ruts which form a serious malaria hazard. It is impossible to eliminate road ruts so long as this condition is permitted to exist. This recommendation for the establishment of roads applies also to the road system in all ration, fuel ammunition, public works and salvage dumps.

C. Airport drainage. There exist serious faults in the drainage system of Henderson Field and Fighter I. The Henderson Field drainage is particularly poor around the north and east sections of the field where numerous laterals are needed to connect with the main ditch already established. At Fighter I the revetments are nearly all surrounded by scooped out pockets which hold water constantly.

D. Abandoned gravel pits along both the Nalimbu and Lunga Rivers are, at times, serious sources of *Anopheles* breeding. It is recommended that units working these pits be required to divert a channel of the river through each pit before the pit is abandoned.

3. Organizational work. It is recommended that all organizations in the area be urged to eliminate road ruts, puddles, and unused fox holes within and adjacent to their camp areas. Insofar as time permits Malaria Control will aid in this work, but such aid can be given only in projects of major importance. An example of such badly needed work is in the 27th NCB camp area and the adjacent Public Works Dump.
4. Dengue Control. In all salvage dumps, in the many unofficial and official trash dumps, and in the Ordnance Motor pool near 20th Sta. Hosp. many artificial containers are producing Culicine mosquitoes. While *Anopheles* may at times breed in such containers the primary hazard is from *Aedes aegypti*."

2. Maps and Mapping

Accurate maps are highly desirable, though not absolutely essential, in survey activities. Their value increases with the increase in extent and complexity of the area under scrutiny, and their greatest value is in expediting the translation of survey activities into actual control. Most military maps such as artillery fire control maps are unsatisfactory for detailed entomological survey work since they do not accurately show water courses and the scale is usually not adaptable to the needs of survey and control units. For this reason survey personnel frequently assumed the responsibility of preparing their own maps of the areas involved, and in some instances, as on Guadalcanal and Espiritu Santo, this activity was coordinated to produce a detailed map of the major portion of the occupied area (fig. 4).

Whenever possible aerial mosaics or photomaps were obtained. Aerial mosaics and contact prints of aerial photographs were found particularly helpful in making a critical analysis of a given territory. Mosaics were utilized a great deal in the preparation of preliminary maps of an area; these maps were then corrected and completed by ground inspection or available survey data. Large scale mosaics,

FIG. 1. SHEET OF 16 SHEETS OF MAP OF NORTH COAST OF GUADALCANAL PREPARED BY PERSONNEL OF THE 63RD NAVAL CONSTRUCTION BATTALION UNDER THE SUPERVISION OF THE ISLAND ENTOMOLOGIST, GUADALCANAL

This map, reproduced by lithographic process at scale 1:24000, was used for purposes of recording larval populations, engineering activities, and various other functions of the survey and control units.

preferable scale 1:5000, were used whenever possible for wall maps in the joint entomological and engineering laboratories (fig. 5). Covered with a transparent overlay of thin celluloid, these mosaics could be used for recording field data by use of colored grease crayons. In lieu of mosaics, large scale maps, reproduced by blue printing or direct printing on sensitized paper, were sometimes used for this purpose. Information recorded in this way gave a graphic presentation from day to day of insect populations, status of control operations and similar information.

Record size maps, scale approximately 1:30000, were used for reports of all kinds in summarizing field data. These were usually reproduced in quantity

FIG. 5. A PORTION OF AN AERIAL MOSAIC USED AS A WALL MAP ON GUADALCANAL, WITH A SHEET OF RECORD SIZE MAP FOR COMPARISON
Transparent overlay removed from mosaic for this photograph. Photo No. 44-6453, 161 Signal Photographic Company

by lithographic process, although often they were photographed or printed on sensitized paper. Reproduction work of this kind was usually done by photographic or engineering units at the request of the malaria and insect control organization. This mapping activity was not an authorized function of the malaria survey units, and the fact that it received the support of the various base commands is in itself evidence of its recognized value in the problems at hand.

3. Integration of Survey and Control Activities

Unless translated into control activities, survey data are of academic value only. Successful integration of survey and control activities depends upon constant liaison between the entomologist and sanitary engineer. Experience indi-

cates that this relation was best established and maintained when the personnel of the survey and control units lived as well as worked together, as was the usual practice in the South Pacific Area. The writers believe that the outstanding success of the malaria control program in the South Pacific was due more to the successful solution to this problem than to any other one factor. It is probable that even better coordination of activities would have resulted had the two functions been united under a single command.

Joint participation in the preparation of outlines of control projects mentioned above was one step in the process of integration of activities. This invariably involved discussion and examination of proposed ditching, cleaning, and filling projects by the entomologist and engineer with a consequent better appreciation of the purposes and difficulties in the work of each. It was endeavored to extend this understanding of problems to the enlisted men of the two commands by a similar, though necessarily less thorough program of joint participation in the various functions of the units.

Specific activities believed important in the integration of survey and control activities are, (a) use of large wall maps which show results of daily surveys for the information and guidance of control crews, (b) frequent assignment of survey men to accompany control crews and point out new breeding sites, and those that had been missed or inadequately treated, (c) use of flags in the field and on wall maps to mark exact locations of breeding sites, thus facilitating the work of the emergency oiling crews, (d) larviciding of small, isolated breeding sites by survey personnel, thus saving the larvicidal crew numerous trips into remote portions of the territory, (e) weekly conferences by survey and control personnel with the officers in charge, (f) use of prepared mimeographed slips giving location and exact information concerning faulty control activities, (g) investigations by survey personnel of problems having a direct bearing on control operations, (h) joint participation in recreational activities and general camp duties by men of the various units.

4. Routine Evaluation of Control Activities

As indicated in the preceding discussion, the survey unit was responsible for a constant and thorough check on the efficacy of control operations. The initial survey of a territory gradually evolved into a routine checking program as control operations became more extensive and complete. This program was basically an analysis of mosquito populations.

Even in areas of high mosquito populations it was impossible consistently to find adults of *A. farauti* in their daytime resting places, except for the blooded females that lingered in native huts and tightly closed tents. Native villages, including native labor camps in the latter phases of the campaign, were nearly always removed from troop bivouac areas, and mosquito population counts in those places were not representative of conditions in the occupied area. Night catches of mosquitoes seldom produced *farauti* in sufficient numbers to be significant, and as control operations progressed populations of all species of mosquitoes became so low as to render significant sampling difficult. For these reasons it

was felt desirable to rely upon larval sampling as a more sensitive index of changes in the population. Whenever adult populations were high, routine night catches were made to supplement larval population counts but as adult populations became meager night catches were discontinued. Light traps, though operated routinely for as much as six months on some bases, were never sufficiently productive to be considered accurate as a population sampling method.

In addition to an analysis of insect populations, the field survey crew was expected to report on work needed to correct potentially dangerous situations, even though actual breeding was not detected. This applied particularly to obstructions of streams and drainage ditching, flume maintenance, and occurrence of unauthorized trash and garbage dumps which might harbor *Aedes aegypti* or become foci of fly breeding. These checking functions covered areas controlled by all organizations, and involved liaison with the malaria and insect control personnel of line and service units of all kinds.

Officer personnel participated in regular inspection of organizations for observance of individual protective measures and general malaria discipline.

5. Records and Reports

In order to provide a basis for comparison of conditions in any one district with those in another, and of conditions within a given district from time to time, detailed records of all survey findings were kept. In addition, complete data on field collections and laboratory rearings of insect material were recorded and associated with material sent to scientific institutions in the States. Such records and material form a permanent record of the insect fauna encountered, and will be of inestimable value to war or peace time activity in tropical areas.

Although a variety of systems was used at different times and on different bases, all were designed to furnish the necessary pertinent data to determine the importance of the species involved. All specimens captured in routine night checks for adults were identified, listed by sex, and, in the case of females, recorded as to whether or not they had taken a blood meal. Sample larval collections were routinely brought in and identified or in many instances reared to the adult stage for subsequent identification. Findings of the field survey crews were recorded, for the information of the control personnel, as to whether they were *Anopheles* or other forms of mosquitoes. Where more than one species of *Anopheles* was found the species were differentiated in reports. Cognizance was normally taken of the presence of *Aedes aegypti*, especially on Guadalcanal where an attempt to wipe out the species was being made.

A common method of recording larval populations was to indicate the number of larvae found over the number of dips taken, thus 150/60, by writing these figures in the appropriate place on a transparent overlay to the wall map. *Anopheles* findings were recorded in red, other mosquito records in blue. The presence of late instars, indicating the necessity for immediate larviciding, was indicated by placing a "+" before the fraction. A locality flagged for attention by the emergency oiling crew was indicated by a red "F" on the overlay. The wall map was constantly consulted by all members of the control and survey

teams, as well as the malariologist. At the end of each checking period these insect population data were transcribed, by appropriately colored ink, to the record size maps for a permanent part of the reports on conditions in the territory.

On Espiritu Santo and Bougainville, survey areas were separated for record purposes into small subdivisions bounded by streams, hills, or other terrain features, or on the basis of territory occupied by specific troop units. In each of these area subdivisions the total number of sampling dips and the total number of *Anopheles* found were recorded during each inspection survey. On the basis of these statistics, translated into the number of *Anopheles* per 100 dips, a population index was computed. This population index proved to be of considerable practical value although on occasion it was somewhat misleading since it did not take into account changes in total water surface. By comparison with previous indices changes in the status of *Anopheles* breeding could be detected immediately in any part of the area surveyed and control emphasis could be directed toward specific localities where populations were becoming more abundant or not responding to treatment. Usually this population index would reflect increasing *Anopheles* densities in sufficient time to prevent accelerated malaria transmission rates by immediately instituting appropriate corrective action.

Responsibility for obtaining and recording pertinent climatological data, particularly rainfall, was undertaken as a survey function. Whenever possible these data were obtained from nearby meteorological stations maintained in connection with airfields; if such stations were not present records of rainfall were obtained by means of improvised gauges.

Monthly, or more often if deemed desirable, the entomologists prepared detailed reports of activities in their assigned districts. These reports covered such items as, (a) summary of survey activities and results, (b) climatological data and a discussion of the influence of weather conditions on insect populations and control operations, (c) reports on investigational projects, (d) participation in training programs, (e) recommendations for control and investigational work, (f) record maps and report forms giving details of insect population sampling.

6. Policy determination

At all times, but particularly in the initial phases of occupation of a new base or territory, the question of policy with respect to insect control methods arose. This was not alone the responsibility of the entomologist but was usually determined after exhaustive discussion of the problems with the malariologist and sanitary engineer. The entomologist, being responsible for recommendations for control procedure, was always vitally interested in this matter and usually in a position to furnish the bulk of the information pertinent to the question. Frequently, of course, policy would be determined by the type of equipment available for control work, in other cases by the decision as to whether control would be attempted largely by larviciding or by semi-permanent control projects. Experience showed that in stream cleaning it was usually unwise to use heavy equipment, see paper I, page 82. As a result it was recommended that all stream

cleaning be done by Melanesian laborers, or by troop hand labor. Decisions as to whether it was easier to fill or drain an area, ditching methods to be used, and so forth, were decided jointly with the engineer.

In general, under wartime conditions, decisions as to methods were made from the standpoint of speed of accomplishment and efficient utilization of available personnel and equipment rather than the dollars and cents cost of a project, since it was recognized that any other policy was potentially disastrous. The quickest control measures were ultimately the cheapest.

E. INVESTIGATIONAL PROJECTS

In addition to the more or less routine and standardized functions having a direct and immediate bearing on the problems at hand, whenever the need arose or conditions permitted the entomologist pursued investigational projects. While these may have a direct bearing on control work they are frequently of a basic character designed to broaden the general understanding of the problem. Details of our present knowledge of the mosquito fauna of the South Pacific Area were either acquired or confirmed by survey personnel working on insect-borne diseases during World War II. Attention of the entomologist was almost continually directed toward the following problems, (a) differentiation of the various species of mosquitoes occurring in the region, (b) host preferences, biting habits, night behavior, daytime resting places, and longevity of adult *Anopheles*, (c) factors determining or limiting suitability of water for mosquito breeding, (d) seasonal changes in the mosquito fauna and in breeding places of particular species, (e) length of the aquatic stages of *Anopheles* in nature, (f) effect of desiccation on *Anopheles* eggs, (g) survival of *Anopheles* larvae and pupae in moisture film on mud or vegetation, (h) susceptibility of larval and adult mosquitoes to certain larvicides and insecticides and its bearing on methods of mosquito control, (i) reaction of adult mosquitoes to repellents, (j) normal flight range of adult female *Anopheles*, and the existence of migrational or dispersal flights and (k) existence of races or physiological strains of *Anopheles farauti* and their importance in malaria transmission.

Other projects that periodically received considerable attention were: (a) determination of the local vectors of filariasis, (b) hosts of trombiculid mites, the vectors of scrub typhus, (c) incidence and species involved in human myiasis, (d) flight requirements for successful application of DDT sprays by airplanes, (e) droplet size analysis of airplane dispensed DDT, (f) suitability of various types of hand sprayers for use in application of larvicides, (g) methods of applying and value of applications of DDT to tentage, mosquito nets, screens, and quarters for residual effect and (h) minimum lethal dosage of insecticides and optimum dosages for practical control.

In many of these problems little progress was made, in others valuable information was gained. It is hoped that those individuals who carried on various phases of the work will publish their findings.

F. FACTORS LIMITING EFFECTIVENESS OF PROGRAM

The following discussion is essentially a critical analysis of the faults apparent in the organization and operation of entomological work in the South Pacific Area. We realize fully that many of these faults are directly traceable to the urgency of the military situation and the necessity of prosecuting a campaign with inadequate personnel and equipment. Nevertheless, it is hoped that these comments will be received in the spirit in which they are presented, one of constructive criticism.

At all times there was need for competent research personnel, adequately equipped, who could devote their entire attention to investigational work. Medical General Laboratories were seldom available, and when present they were either uninterested or incapable of conducting the critical studies needed. Malaria Survey Detachments included many competent investigators but these individuals were invariably so overloaded with the urgent current problems connected with control operations that they had little time for carrying out long-time experiments. It would have been highly desirable, when sufficient personnel became available, to assign certain units exclusively to investigational work. This was actually done for a brief time on Guadalcanal. However, such an arrangement posed serious problems in personnel management. Most entomologists were anxious to participate in research work, and the younger men in particular, realizing that their professional future to some extent depended upon their demonstrated ability to carry out research projects, were eager to have equal opportunities in this respect. The problem would appear to be best solved by the organization of entomological units designed for investigational work and having no other duties.

The laboratory equipment of the Malaria Survey Detachment was primarily designed for parasitological work and the entomological equipment was noticeably inadequate. Such small but essential items as aspirators were never included. Literature was scanty, and current literature, or information as to its existence, was difficult to obtain. In order to carry on serious entomological work or even adequate routine survey work in isolated overseas posts, it was necessary to improvise much of the equipment.

There was constantly felt a need for entomological assistance from higher command echelons. Entomologists, or others with an understanding of the needs of field workers, could have been invaluable in channeling to the overseas units pertinent information, and in expediting the procurement of unusual items of equipment.

The shortage of personnel and equipment in the early phases of the campaign has been alluded to elsewhere. This situation was by no means peculiar to malaria survey activities, but was nevertheless at times critical in that phase of the work. At one time on Guadalcanal one officer and five enlisted men, with two "jeeps" for transportation, were responsible for the field survey work of approximately 45 square miles of territory, all of it new to the personnel and half of it

the newly occupied Tetere area, soon to become the staging area for a Marine Division. Within two weeks after the beginning of survey activities it was necessary to submit recommendations for projects to be undertaken by a Naval Construction Battalion, while at the same time preparing maps, establishing a laboratory, and guiding the efforts of the larviciding crew. This example, while extreme, was not considered unusual in the early phases of the Solomon campaign. The subsequent arrival of additional army personnel, adequately equipped with authorized transportation, fortunately corrected this situation.

A critical evaluation of officer personnel and their place in the malaria and insect control program is a difficult problem. While recognizing the need for over-all coordination of this program, we feel that in many instances the choice of Medical Corps Officers for this function was not necessarily a wise one except in theory. In actual practice this arrangement often meant that medical officers with little or no background in preventive medicine and medical entomology and hence unqualified to exercise broad judgment in the development of a program were supervising the activities of well trained and thoroughly competent entomologists and sanitary engineers. The prime prerequisites for successful planning and supervision of a malaria and insect control program are sound basic training and the ability to exercise good judgment. Experience showed that medical corps personnel did not always possess these attributes to the desired degree.

Normally the direction of the larvicidal program was considered a function of the sanitary engineer and in relatively few instances was this work directed by the entomologist. In general it is believed that the larvicidal program could have been handled more expeditiously by the entomologist since the field survey personnel under his direction were usually more familiar with breeding sites and larval populations than was any other group. Insect control, particularly the application of insecticides, is a normal function of entomologists for which many are especially trained. This arrangement would have been particularly desirable on those bases where the engineer was responsible for numerous draining, filling, and construction projects which involved the operation and maintenance of considerable heavy equipment; these activities usually required the major portion of the engineer's time and frequently led to inadequate supervision of the larvicidal program.

Little critical survey or control work could be accomplished under combat conditions. In retrospect, the desirability of undertaking survey activities in the first few days of a military operation seems questionable. Rather it is believed that control work at such times should consist largely of individual protective measures and such larviciding as can be done by the combined survey and control personnel. As the military situation permits regular survey activities can be initiated.

After combat ceased on many bases there was a tendency for incoming organizations to bivouac in previously unoccupied sections as well as for organizations previously present to move to apparently more desirable locations, thus expanding

the occupied area of the base and greatly increasing the territory to be controlled. On large bases such as Guadalcanal this promised to be a very serious problem until, at the request of the malaria and insect control organization, the island command eventually established a boundary limit beyond which organizations could not bivouac except in those cases where the location was dictated by tactical reasons. Even with this restriction there still existed factors which served to minimize control efforts. Combat teams often chose to hold maneuvers, usually involving night operations and patrols, outside the controlled area. Numerous individuals and small groups, for purposes of recreations, or rarely on business, journeyed into the uncontrolled portions of the island and stayed overnight or lingered after dark without adequately observing individual protective measures. On the basis of the first attacks, many cases of malaria could be traced to such injudicious trips to native villages or outposts.

MALARIA AND OTHER INSECT-BORNE DISEASES IN THE SOUTH PACIFIC CAMPAIGN 1942–1945

IV. Parasitological Observations on Malaria in Natives and Troops, and on Filariasis in Natives

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The parasitology section of the Army-Navy Malaria and Insect Control Organization was headed by a commissioned officer parasitologist (Army Sanitary Corps or Navy H-V (S)), and included a senior non-commissioned officer in charge of the parasitology laboratory and 1 or 2 enlisted laboratory technicians. The parasitology section carried out malaria surveys among natives, white civilians, troops and Japanese prisoners to determine the incidence and geographical distribution of this disease and to check the efficacy of drug and other control measures. It carried out surveys to determine the incidence of filariasis and other parasitic diseases in natives and troops. It provided a microscopic diagnostic service for dispensaries, sick bays and other installations which were not equipped to do this work. The magnitude of the diagnostic service may be seen from the fact that in 1943 alone over 75,000 slides were read. In addition, the malaria diagnoses made by hospitals, sick bays and aid stations which read their own slides were checked periodically to ensure the reliability of their findings. The parasitologist participated in the malaria control training program and in other work of malaria control officers, such as inspection of troop areas for malaria discipline, and also collected and compiled statistical data on malaria incidence in military personnel.

This paper presents the results of surveys of malaria and filariasis in natives and observations on the species of *Plasmodium* found in troops.

A. SURVEYS OF NATIVES

The only information on malaria in the Solomon Islands before the war which was available to the Army and Navy Malaria and Insect Control Organization was the report of Sayers (1943), who had conducted a hospital at Munda, New Georgia and later at Vella LaVella from 1927 to 1934. During this period he treated 741 parasite-positive cases of clinical malaria, most of which came from a population of about 6000 in the New Georgia group of islands. He found *Plasmodium falciparum* in 44% of these cases, *P. vivax* in 32%, and *P. malariae* in 18%; the species was not determined in 6%. Mixed infections were present in 3% of the group. He found that during the first and second years of life, vivax malaria was the most common; that all three species were about equal in incidence from 3 to 5 years of age; that from 5 to 10 years of age, *P. falciparum* accounted for

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over half the cases, followed by *P. malariae* and *P. vivax*; and that in natives over 10 years of age, *P. falciparum* caused 82% of the cases, *P. vivax*, 12%, and *P. malariae*, 6%. Clinical malaria was uncommon in natives over 30 years old. In a spleen survey which he carried out among 365 children in the New Georgia group, he found a splenomegaly rate of 73%. Sayers found that the malaria season was from January to June, occurring during and immediately following the rainy season. The most malarious months were April, May and June, the incidence of the disease being highest in June.

In order to determine the incidence of malaria and filariasis among the natives on the islands where troops were stationed, and hence the extent of the danger to troops which they represented, numerous surveys were carried out by personnel of the malaria survey units in the theater. The data presented herein were compiled from reports of the parasitologists of these units which were available at the Guadalcanal Malaria Control Headquarters and at the Theater Headquarters. Only a small proportion of these surveys was carried out by the authors. Since the authors are not now in possession of the original reports, it is impossible to give a complete list of the names of those who carried them out.[3] The present report gives an overall picture of the findings in the South Pacific; it is expected that the results of special studies will be reported separately by other members of the Malaria and Insect Control Organization.

These surveys were made during a two-year period from August 1942 to August 1944. All persons examined in the Solomon Islands and Bismarck Archipelago were Melanesians. In the New Hebrides, most of those examined were Melanesians, but also included is a number of Indo-Chinese who had been imported as laborers.

The blood examinations on which the data are based were made on Giemsa-stained, thick smears. In some surveys, thin smears were also made for use if species identification was uncertain in the thick smear. Only a single smear was made from each individual.

1. Malaria in Natives

Incidence of malaria. In Table I are given the incidences of malaria on the islands studied. There is no malaria on New Caledonia, Samoa and Figi, since no *Anopheles* occurs on these islands. The figures in this table indicate persons in whose blood parasites were found, not clinical malaria cases, and are thus not comparable with Sayers' figures. These surveys were made on persons of all ages, but mostly on adults. They were made at all seasons of the year, but the data are inadequate to demonstrate seasonal variations.

[3] As an example of the number of persons involved, the surveys reported from Guadalcanal, Savo, Florida, Malaita, San Cristobal and Green Islands were performed by the following officers, assisted by numerous enlisted men whose names are not available: John G. Arnold, Jr., Curtis A. Beerman, Virginius E. Brown, Joseph H. Denton, Jr., Henry W. Deurloo, Paul Harper, Norman D. Levine, Otto L. Munch, R. C. Page, David Schiffer, Ralph J. Schlosser, Louis E. Schopick, Carlos D. Speck, Robert T. Stevenson, and Monroe M. Vincent.

The surveys on natives of Malaita and San Cristobal were carried out on adult males who had been recruited as laborers by the British Protectorate Government, and who were living in labor camps on Guadalcanal at the time of examination. The surveys of Guadalcanal natives are divided into those made on a similar group of adult male laborers and those made on persons of both sexes and all ages living in villages outside the troop area. The malaria parasitemia rates of these latter two groups (52% for the villagers and 10% for the laborers) were markedly different. Part of this difference was due to the fact that the incidence of malaria decreases with increasing age, and part probably to the fact

TABLE I

Incidence of malaria parasitemia among South Pacific natives

ISLAND	NUMBER OF SURVEYS	NUMBER EXAM.	PARASITIC INDEX (%)	
			Average	Range
New Hebrides				
Efate	12	4000	10	5–50
Espiritu Santo	6	4000	13	7–57
Solomons				
Guadalcanal				
Villagers	15	451	52	6–74
Laborers	1	106	10	
Total	16	557	44	6–74
Savo	4	427	26	11–39
Florida	1	37	65	
Malaita (Laborers)	6	286	11	4–19
Russells	3	193	64	57–73
Bougainville	1	500	10	
San Cristobal (Laborers)	1	57	7	
Treasury	1	37	16	
Bismarck Archipelago				
Green*	2	350	45	43–48
Emirau	2	313	16	12–21

* Smears made one month after evacuation to Guadalcanal.

that in the selection of laborers by the recruiting officers, only vigorous, healthy-appearing individuals were accepted. So far as is known, none of these men had received atabrine prior to examination. The parasitemia rates of the Malaita and San Cristobal laborers (11% and 7%), respectively were similar to those of the Guadalcanal laborers, which suggests that these rates cannot be taken as indicative of the true malaria rates among villagers on these islands.

The survey on natives from Green Island was carried out on Guadalcanal. This group had been evacuated to Aola Bay on Guadalcanal, about 25 miles east of the troop area, and was examined about a month after its arrival there. It had very little contact with Guadalcanal natives prior to examination.

Plasmodium species distribution. In Table II are given the species of *Plasmodium* encountered in the surveys. The most common species on all islands

except Emirau was *P. vivax*. On the other islands, this species was identified in from 44% to 88% of the positive smears (exclusive of mixed infections). The next most common species was *P. falciparum*. On Emirau it was the commonest, being found in 45% of the positive slides, while on the other islands its incidence ranged from 6% to 37%. *P. malariae* was encountered on Espiritu Santo, Guadalcanal, Savo (more prevalent than *P. falciparum* on this island), Florida, Russells, Green and Emirau, but not on Efate, Malaita, San Cristobal or Treasury. Its incidence on the different islands ranged from 0.5% on Espiritu Santo to 25% on Emirau.

Relation of age to incidence of malaria. In Table III are given the data available on the relation of age to the incidence of *Plasmodium parasitemia* in natives

TABLE II

Plasmodium species distribution among South Pacific natives

ISLAND	NUMBER OF SURVEYS	NO. OF POS. SMEARS	PLASMODIUM SPECIES (%)				
			vivax	falcip.	malar.	Mixed	Undeterm.
New Hebrides							
Efate	5	205	66	25		4	4
Espiritu Santo	5	486	57	37	0.5		5
Solomons							
Guadalcanal	14	200	60	18	12	6	4
Savo	3	103	56	13	20	11	
Florida	1	24	79	12	8		
Malaita	5	29	67	21			12
Russells	3	123	41	30	4		25
San Cristobal	1	16	88	6			6
Treasury	1	6	84	16			
Bismarck Archipelago							
Green*	1	132	46	14	1	8	31
Emirau	1	25	29	45	25		

* Smears made one month after evacuation to Guadalcanal.

of Guadalcanal, Savo, Green, and the Russell Islands. Three age groups (birth to 5 years, 6 to 15 years, and over 15 years) were selected for purposes of comparison in the Guadalcanal and Savo surveys. In the Green Island survey the younger two age groups were birth to 3 years and 4 to 15 years, while in the Russells surveys the age groups are 0–4 years, 5–14 years, and over 14 years. The ages in these surveys were estimated by the examiners. It is seen that the parasitemia rate decreased markedly with increasing age. Among Guadalcanal natives, for example, the rate in the 0–5 age group was 91%; in the 6–15 age group. 72%; and in those over 15 years, 38%. The rates for the other islands are similar.

The incidence of the different species varied with age, also. On Guadalcanal, *P. vivax* was the most common species in all age groups; *P. falciparum* was the least common species in the 0–5 group, but its incidence increased concomitantly with a progressive decrease in the incidence of *P. malariae*, so that the latter

species had the lowest incidence in the two older age groups. Trends are not so clear in the other surveys.

TABLE III

Relation of age to incidence of malaria among South Pacific natives

AGE GROUP	NUMBER OF SURVEYS	NO. OF PERSONS	% POS. SMEARS	PLASMODIUM SPECIES (%)				
				vivax	falcip.	malar.	Mixed	Undeterm.
0–5 yrs.								
Guadalcanal	5	44	91	47	13	25	15	0
Savo	1	27	96	50	0	31	20	0
Green*	1	33	88	69	7	0	10	14
Russells†	3	59	92	54	30	4	7	6
6–15 yrs.								
Guadalcanal	5	51	72	54	32	11	5	0
Savo	1	28	75	67	5	19	10	0
Green*	1	96	56	68	9	0	13	9
Russells†	3	45	76	42	31	3	3	22
Over 15 yrs.								
Guadalcanal	5	96	38	67	28	3	0	3
Savo	1	88	17	67	7	27	0	0
Green*	1	175	28	8	24	2	0	65
Russells†	3	89	36	25	37	6	0	31

* Smears made one month after evacuation to Guadalcanal. Age groups in this survey are 0–3 yrs., 4–15 yrs., and over 15 yrs.

† Age groups are 0–4 yrs., 5–14 yrs., and over 14 yrs.

TABLE IV

Splenomegaly among South Pacific natives

ISLAND	NUMBER EXAM.	% WITH SPLENOMEGALY
New Hebrides		
Efate	110	61
Espiritu Santo	101	57
Solomons		
Guadalcanal	258	73
Florida	37	70
Malaita (Laborers)	219	57
Russells	193	66
Bougainville	500	75
San Cristobal (Laborers)	219	57
Treasury	37	34
Bismarck Archipelago		
Green	542	65
Emirau	263	85

Splenomegaly rates. The incidence of splenomegaly among natives of all ages on the different islands is given in Table IV. Spleen rates varied from 34% on Treasury Island to 85% on Emirau. In some surveys, spleen classification was recorded. These figures are given in Table V.

2. Filariasis in Natives

It has long been known that there is a high incidence of filariasis due to *Wuchereria bancrofti* in Samoa and Fiji, but very little was known about its incidence in the Solomon Islands. Filariasis surveys were carried out by parasitologists of the malaria survey units, and also by a special Navy Filaria Survey Unit

TABLE V

Spleen classifications among South Pacific natives

ISLAND	NUMBER OF SURVEYS	NO. OF PERSONS	PER CENT SPLENOMEGALY	SPLEEN CLASSIFICATION (%)				
				PDI	+	++	+++	++++
Efate	1	110	61	6	22	39	28	4
Guadalcanal	6	244	85	3	27	40	27	3
Florida	1	37	70		46	35	12	8
San Cristobal	1	219	57		23	31	34	12
Russells	3	193	66	9	26	41	16	6

TABLE VI

Incidence of microfilariae among South Pacific natives

ISLAND	INDIGENOUS NATIVES*, WUCHERERIA BANCROFTI		INDO-CHINESE, WUCHERERIA MALAYI	
	No. exam.	% positive	No. exam.	% positive
Samoan Area	?	24†		
Fiji	300	30†		
New Caledonia	247	4†		
Loyalty	270	12†		
New Hebrides				
Efate	110	17‡		
Espiritu Santo	?	22‡	?	9
Solomons				
Guadalcanal	2500	22‡		
Bismarck Archipelago				
Emirau	62	39‡		

* Melanesians on all islands except Samoa; Polynesians in the Samoan area.

† Non-periodic.

‡ Nocturnal periodicity.

whose officers were E. E. Byrd and L. S. St. Amant. An abstract of the work of this group has been published by Byrd (1945). The results of these plus the other filariasis surveys are given in Table VI. The figuries show the percentages of individuals examined in whose circulating blood microfilariae were found in Giemsa-stained, thick blood films. Children were not included in these surveys.

No periodicity was found in the appearance of *W. bancrofti* microfilariae in the blood in Samoa, Fiji, New Caledonia or the Loyalty Islands, but nocturnal periodicity was observed in the Solomons, New Hebrides, and Emirau. This could be correlated with the habits of the vectors. In Samoa and Fiji, the

principal vector of filariasis is the day-feeding mosquito, *Aedes scutellaris pseudoscutellaris*; in the Solomons and New Hebrides it is probably the night-feeding mosquito, *Anopheles farauti laveran*.

With one exception, *Wuchereria bancrofti* was the only filariid species found in these surveys. On Espiritu Santo, however, the Navy Filaria Survey Unit found *W. malayi* microfilariae in 9% of the Indo-Chinese who had been imported as laborers under the Condominium Government. This species was not present in the Melanesians, and no vector for it was found on the island. It is apparent that these infestations had been acquired in Indo-China prior to migration to the New Hebrides.

B. PLASMODIUM SPECIES IN TROOPS

The malaria encountered among troops in the South Pacific Area was caused almost entirely either by *P. falciparum* or *P. vivax*. Cases due to *P. malariae* were rare.

The predominant species showed a characteristic change in malarious islands of this area where adequate studies were made. Early in the campaign, falciparum infections predominated, but as control measures improved in efficiency and as the general malaria rate decreased, the proportion of vivax infections steadily increased. This is shown in figure 1, compiled from data on laboratory-confirmed cases on Guadalcanal.

In January, 1943 there were twice as many cases of falciparum as of vivax malaria. The incidence of the two species was almost equal in July; and in January, 1944, there were twenty times as many vivax as falciparum cases. It should be noted here that the total malaria rate for Guadalcanal for January, 1943 was 1042 per thousand per annum; for July, 1943 it was 608 per thousand per annum; and for January, 1944 it was 200 per thousand per annum.

Several factors were associated with this sequence of events. In January, 1943 mosquito control and personnel protection were still inadequate, and a condition of hyperendemicity existed. Under these conditions, a large percentage of the falciparum cases at this time were probably mixed infections in which *P. vivax* was suppressed. That this antagonistic action is common has been shown by Boyd and others. During this early period, the malaria cases were almost all primary, but as time went on an increasing percentage were relapses. Vivax malaria has a very much greater tendency to relapse than does falciparum malaria, and this factor acted to increase the proportion of vivax cases progressively. This shift in species distribution presented a seed-bed containing an increasingly higher proportion of vivax cases to the mosquito vectors; consequently they transmitted a progressively higher percentage of new vivax cases as time went on. In addition, as malaria control became effective and decreased the transmission rate, double infections became less common, so that vivax malaria was no longer masked as much as before by falciarum malaria. Improvement in atabrine discipline also contributed to the decline in falciparum malaria, since this drug has a curative effect in the full sense of the word against *P. falciparum* while it only results in a clinical cure of *P. vivax* malaria. It suppresses both species.

Parasite species incidence after removal of infected troops to non-malarious areas. When infected troops were transferred from hyperendemic territory to non-malarious areas for rehabilitation, *P. vivax* rapidly became the dominant species.

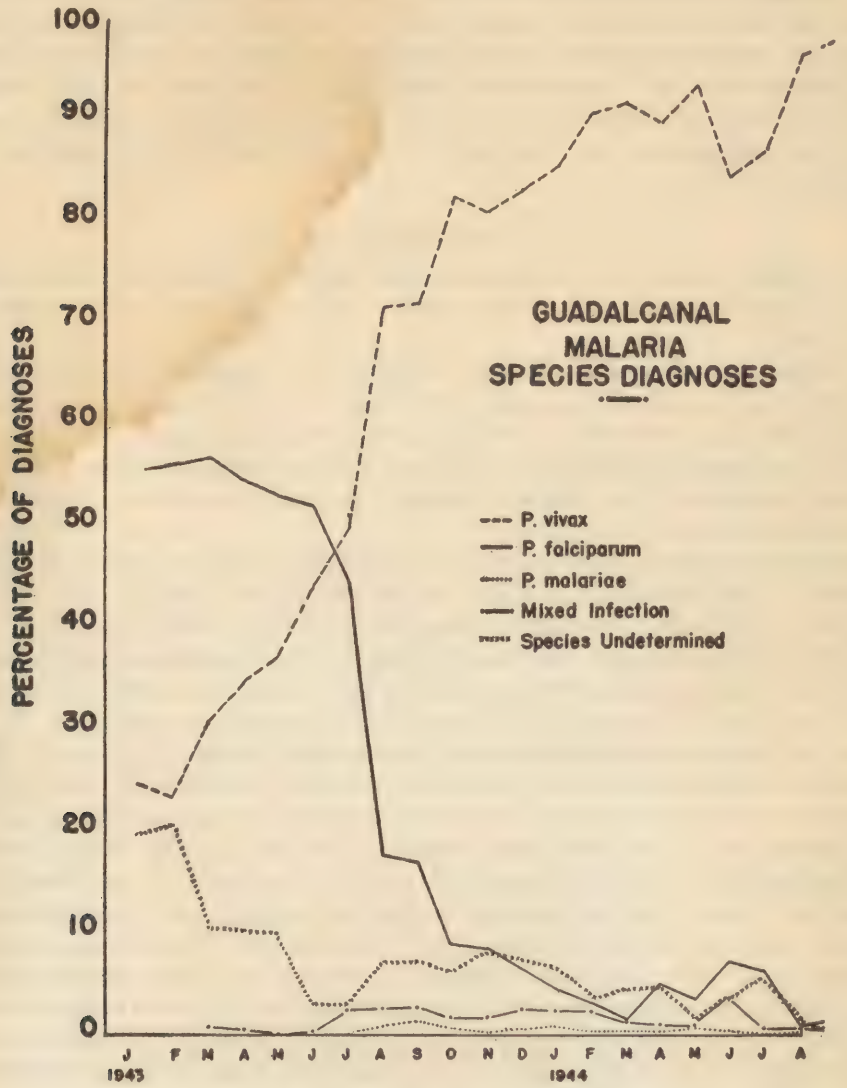

FIG. 1. SPECIES OF PLASMODIUM AMONG TROOPS ON GUADALCANAL

It was the general experience of hospitals in rear bases in the South Pacific and in the United States that many individuals who had falciparum malaria on Guadalcanal or other malarious bases had vivax malaria when they relapsed later on.

Table VII shows the progressive increase in percent of vivax malaria in more than 8000 "first attacks of malaria in New Zealand" occurring in the 2nd Marine

Division, which was moved from Guadalcanal to New Zealand during early February, 1943. These "first attacks" were the initial ones recorded in New Zealand, and were not necessarily primary attacks since many of these patients had had malaria on Guadalcanal.

The percentage of *P. vivax* infections increased from 67 in February to 99 in June, while that of *P. falciparum* decreased from 27 in February to 0 in June. The figures given for January are those of Guadalcanal as a whole, and have been inserted for purposes of comparison. It should be mentioned that all members of this division had mass therapy with either quinine or atabrine enroute to New Zealand.

The disappearance of *P. falciparum* malaria a few months after leaving a malarious area occurred in many well-studied groups.

TABLE VII

Plasmodium species in troops following departure from malarious area

PLASMODIUM SPECIES	PERCENTAGE OF TOTAL CASES					
	Guadalcanal*, Jan. 1943	New Zealand†				
		Feb.	Mar.	Apr.	May	June
vivax	24	67	74	92	96	99
falciparum	55	27	12	4	1	0
Mixed	0	4	9	3	1	0
Undetermined	19	2	4	1	2	1

* All troops.

† 2nd Marine Division.

C. DISCUSSION

It should be mentioned that percentage incidences of malaria parasitemia and of microfilariae listed in the various native surveys are probably not strictly comparable. In the malaria surveys, differences in age composition of the surveyed groups strongly affect the resultant rate, since it is much higher in children than in adults. In surveys made by different individuals, a certain amount of variation is to be expected because of personal factors, such as the amount of blood used in making the smear, the amount of time spent in searching each smear, and the efficiency of the microscopists. Nevertheless, the figures given here are considered sufficiently reliable for practical purposes.

Malaria is obviously hyperendemic among the natives of the Solomons and New Hebrides. The very high parasitemia rates in children, the lower rates in adults, and the high spleen rates all indicate this fact. Filariasis, too, is a disease to be reckoned with, not only in Samoa and Fiji, but also in the Solomons and New Hebrides.

D. SUMMARY

1. Malaria parasitemia rates among natives of the Solomon Islands, New Hebrides and Bismarck Archipelago as determined by malaria survey units in

the South Pacific between 1942 and 1944 are presented. They show that malaria is hyperendemic in this area.

2. *Plasmodium vivax* was the most common species encountered in these surveys. *P. falciparum* was second in incidence, and *P. malariae* third. Relative incidences of the three species varied on the different islands.

3. The incidence of splenomegaly among natives varied from 34% to 85% on the different islands, but on most was between 50% and 75%.

4. The incidence of microfilariae of *Wuchereria bancrofti* among the natives varied from 4% on New Caledonia to 39% on Emirau. The rate was 22% on Guadalcanal and Espiritu Santo, 24% in the Samoan area, and 30% in Fiji.

5. Nocturnal periodicity of microfilariae was noted on Guadalcanal, Espiritu Santo and Emirau. There was no periodicity in Samoa or Fiji.

6. *Wuchereria malayi* was found in 9% of imported Indo-Chinese laborers on Espiritu Santo, but not among the natives on any of the islands surveyed.

7. In the early part of the South Pacific campaign, the predominant type of malaria among troops was caused by *P. falciparum*. The falciparum-vivax ratio decreased progressively, so that in the latter part of the occupation vivax malaria was far more common than falciparum. This shift was associated with a marked decrease in the general incidence of malaria.

8. Upon removal of troops from a malarious area, *P. vivax* rapidly became the predominant cause of malaria.

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